MALARIA CONTROL
BY ANTI-MOSQUITO MEASURES

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BY ANTI-MOSQUITO MEASURES

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PREFACE TO SECOND EDITION

IN this edition a new chapter has been added dealing with the more important advances which have been made in malaria control methods during the past ten years The various subjects have been treated in the same order as in the original edition

The literature relating to anti mosquito measures has become very extensive and the bibliography, which is believed to be reasonably complete now includes 1,148 references as against 570 in the first edition In cases where the title is not sufficiently explanatory, the subject is indicated by a footnote placed immediately below the reference

January 1941

PREFACE TO FIRST EDITION

SINCE the immense importance of the rôle played by mosquitoes in the transmission of disease has come to be generally recognized, the literature dealing with the application of various anti mosquito measures has become so extensive that it is difficult for the average malaria worker to keep in touch with the different methods advocated In the following pages an endeavour has been made to give some account of these methods in a convenient form

It is impossible in a work of this kind to deal really adequately with the subject of drainage, which is largely a matter for the skilled engineer, but a brief description has been given of most of the points of practical importance to the malariologist Other important measures, such as screening, oiling and the use of paris green, have been treated in considerable detail, whilst an attempt has been made to make some reference to all the measures which have been advocated in the literature

An important feature of the book is the bibliography which contains 570 references to books and articles dealing with the subject These have been arranged for convenience under the headings of the various measures dealt with A list of the sources of various apparatus used in the application of anti mosquito measures is given as an appendix

It is hoped that the description of the various measures which have proved of practical importance will make the book of value to the man in the field, and that the bibliography will be of service to malariologists generally

I wish to express my thanks to Dr G Macdonald, of the Malaria Survey of India*, for many helpful suggestions, and for kindly taking the photographs which are reproduced in Plates I and II

May 1931

* This organization is now designated The Malaria Institute of India

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PART I.

PROTECTION AGAINST BITES OF MOSQUITOES

1. Nets.—The use of nets as a protection from the bites of mosquitoes has been practised from very early times. Ross[37] notes that they were employed by the Romans and were alluded to by Herodotus, Horace, Juvenal and other early writers. They still remain the most important of all measures of personal protection against the bites of mosquitoes. A mosquito net should always be used in any malarious locality whatever other precautions may be adopted.

The size of the openings in the netting is important, and this is determined not only by the number of holes to the inch but also by the thickness of the cotton of which the netting is made. The mesh is stated in terms of the sum of the number of holes counted along a line of the warp and a line of the bobbin within an area of one square inch, the hole at the bobbin falling square where the two lines meet being counted twice (Fig. 1). Cotton is graded according to weight and in terms of the ratio of the accepted factor of 840 yards to one lb. The mosquito netting supplied to the British Army in India is of 25/26 mesh, woven of 30's cotton. This means that the sum of the holes counted along a line of the warp and a line of the bobbin in one square inch is 25 or 26 and that the cotton of which it is woven goes thirty times 840 yards to one lb.[48] It does *not* mean that there are 25 or 26 holes to the square inch or linear inch of netting; in fact the number of holes to the square inch would be about 150. Netting of this type is, however, not infrequently misleadingly referred to as being of '25/26 holes to the square inch.'

C, MC

The material should be white, to allow of easy detection of mosquitoes. The top as well as the sides of the net should be of netting and not of calico, as the latter excludes air. The best pattern is the rectangular net, and the next best a bell net with a circular hoop a yard or two above the bed, to allow of the necessary stretching of the net. Not a single rent or hole in the net should be allowed, and there should be no openings in it for the purpose of entering the net.

If possible a large bed and net should be used, so that the hands, knees and elbows may not be pushed against the net during sleep, and thus be bitten through it by mosquitoes outside. If these are not available, a loose valance of gauze or a strip of calico should be sewn round the lower part of the net for a height of about 9 inches above the upper surface of the bed. The net should be made especially full at the corners, and it is an advantage to have webbing sewn diagonally across the top of the net to take the strain.

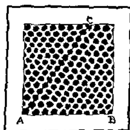


FIG. 1

Method of counting the mesh of cotton netting. The mesh is the sum of the number of holes counted along the lines *AB* and *AC*, the hole at A being counted twice (after MacArthur[89])

The net should be hung *inside* the poles and tucked continuously all round under the mattress, and not be allowed to hang down to the floor. It should be let down before dark in the evening, and should be stretched as tight as possible in every direction to allow the air to pass freely through it. When going to bed a thorough search should be made for any mosquitoes which may be inside the net, preferably with an electric torch. The net should be put up in the morning by collecting the hanging portion together, twisting it into a coil and throwing it over the top bar of the frame.

When travelling by train in malarious localities, difficulty is often experienced in suspending a net in a railway compartment. Small hooks attached to rubber discs, which will adhere by

suction to any smooth surface, can now be obtained, and will be found most useful for this purpose.

2. Mosquito Boots are very useful to protect the ankles in the evening. These may be made either of soft leather, or of canvas. Wellington boots may also be used for this purpose.*

3. Veils and **Gloves** are sometimes used to protect men when on guard at night. Ross[37] recommended the use of a **hand-fan**, an excellent substitute for which is a palm leaf.

4. Repellents or Culicifuges.—The common drawback of all these is that after a certain length of time their effect wears off, but they have their value where men have to be out at night for limited periods in malarious situations. They are also useful for application when people are sitting out of doors during those sultry evenings which are so common in the tropics in the malaria season. Dover's preparation (formula *d*) is particularly suitable. Its smell is not unpleasant, and it may be applied as a pomade to the hair to deter mosquitoes from biting the neck and face[460]. The requirements to be aimed at are as follows:—

(i) It must spread easily.

(ii) It must be of such consistency as to make it adhere strongly to the skin.

(iii) Its base must hinder the too rapid volatilization of the substances which it contains.

Bacot and Talbot[458] concluded that the protection afforded by culicifuges does not result from the dislike of the insect for the preparation but from the latter obscuring the attractiveness of the human odour. They found that culicifuges prepared with grease were more easily applied but not so lasting as those put up with wax. The least possible proportion of the inert base should be used in making up the preparation.

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* A pillow case drawn up over the feet and legs is a useful precaution for ladies when dining. Joss sticks (e.g., 'Katol') may also be burnt under the table to keep mosquitoes away.

A vast number of culicifuges have been recommended the composition of a few of them being given below —

(a) *Bamber Oil* —Oil of citronella 1½ parts liquid paraffin 1 part coconut oil 2 parts carbolic acid 1 per cent

(b) Vaseline 100 parts naphthalene 10 parts camphor 1 part

(c) Castor oil 1 part alcohol 1 part oil of lavender 1 part

(d) Oil of citronella ½ oz spirits of camphor ½ oz cedar wood oil ½ oz white petroleum jelly 2 ozs (Dover s formula[460])

(e) Fowler[16] in Palestine found vermijelli the best repellent for field use

(f) Anti mosquito sprays such as Flit sprayed over the feet and ankles are useful in repelling mosquitoes for a considerable period (*see* under Sprays)

Among other substances recommended may be mentioned sulphur petroleum bergamot oil thuja oil cinamic aldehyde anisic oil a mixture of tar and oil oil of eucalyptus ammonia powdered sandal wood oil of peppermint lemon juice and vinegar oil of turpentine etc

Rudolfs[466] found that the best effects were gained by mixing the repellent with vaseline talcum powder corn starch etc He found that pyrethrum extract (with vaseline) and clove oil gave protection for from 100 to 1?0 minutes whilst oil of lime pennyroyal and rose geranium were effective for 90 minutes

Mention should also be made of the carefully conducted experiments of Bunker and Hirschfelder[457] into the respective merits of a very large number of repellents

Whatever preparation may be used should be applied liberally, especially about the neck and wrists as the sweating induced by tropical climates tends to make the effects transient

Coogle[458] in the U S A noted that anophelines were less numerous under railway bridges the timbers of which had been

treated with creosote oil than under the neighbouring road bridges not so treated and he recommended the application of creosote oil to the walls and ceilings of houses as a mosquito repellent Fermi[26], however who tried this method in Italy reported that it was ineffectual

(See *Bibliography* Nos 456–467)

5 Screening of houses barracks etc

The use of screening especially where electricity is also avail able for light and fans has made a great difference to the health and comfort of those who are able to occupy well built houses in the tropics It is however essential to screen not only sleeping quarters but also other living rooms and more especially verandahs and to provide if possible overhead fans in these also Otherwise the inevitable result will be that people will sit about outside the building in the hot weather till a late hour at night, probably with a large part of their persons exposed to the bites of mosquitoes

In the case of troops it should be insisted on that the men go inside the screened barracks at sunset and remain there If this is impracticable strict orders should be issued that shorts must be replaced by slacks at sunset and that either jackets must be worn or the sleeves of the shirt pulled down

The value of screening has been generally recognized for many years in America Africa Italy and Malaya in which countries it is extensively employed During the last few years it has been introduced in the barracks of British troops in certain cantonments in India with excellent results The following are the principal points to be observed —

The building to be screened must be well built and in good repair

Door frames should be made of seasoned wood with iron brackets at the corners and should not sag on their hinges A double wire attached diagonally across the lower half of the door and tightened up with a turnbuckle will tend to prevent this

No attempt at edge fitting should be made The door should be made to fit against a ¾ inch batten all round the inside, and sufficient space allowed for the door to swell in wet weathers without scraping at the bottom

A light strip of wood should be nailed across the door frame at about the height of a man's shoulders This is to push against when opening the door

There should be two fastenings for each door, one half-way up the top section and one near the bottom The lower panel of the door may be strengthened by wire netting,* as a protection against kicks and against dogs attempting to enter or leave the building Doors should open outwards, so that any mosquitoes resting on them may be driven out when they are opened They should be placed if possible on the windward side of the house, for mosquitoes tend to congregate on the leeward side It is of great advantage to have double doors, with a porch or vestibule at least 6 feet in length between them Strong springs should be fitted to the doors to ensure that they shall remain tightly closed when not in use

Every aperture in the building should be screened In the case of chimneys Coogle[471] recommends the suspension of a wire cage containing naphthalene balls inside the chimney about two feet from the top It may be mentioned, however, that Bunker and Hirschfelder[457] state that mosquitoes appear to be indifferent to the odour of naphthalene

No removable screens or shutters should be used

No screening should be used within one foot of the floor, because it is liable to be damaged when the floor is scrubbed

No furniture should be placed against the screening

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* If the gauze employed is of copper, the protecting netting should also be of copper and not of plain or galvanized steel in order to avoid galvanic action The aperture of the netting should be sufficiently small to prevent the ends of canes, umbrellas, etc, from passing through and damaging the gauze

Orenstein[454] states that if copper gauze is used it should be fastened with copper tacks, and the rows of tacks covered by thin strips of wood, to avoid electrolization

As regards the type of gauze to be used for screening, there are several points to be considered

(i) *Size of Aperture* —As in the case of mosquito netting, the size of the openings in the screen is of the first importance It is insufficient merely to state the number of openings to the linear inch because the size of aperture will vary with the diameter of the wire used It may be increased or reduced by 50 per cent by the adoption of a thinner or thicker wire (Fig 2) The diameter of the wire may be expressed by the number of the gauge, but

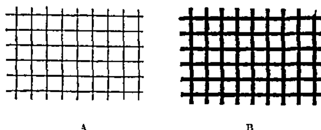


FIG 2

Two types of wire gauze Both are of the same mesh, but the aperture of B is less than that of A by one third, owing to the greater diameter of the wire

unfortunately there are several different gauges in use, each of which denotes a different diameter of wire for the same number Thus Imperial Standard Wire Gauge (I S W G) No 30, denotes a diameter of 0 0124 inch whilst Steel Wire Gauge (S W G), No 30 denotes a diameter of 0 014 inch To avoid confusion it is therefore best to specify sizes of wire in decimals of an inch Another source of confusion is that some authors in referring to size of aperture speak of the area in square inches, whilst others speak of the breadth of the opening in linear

inches The latter notation is the more usual and will be adopted here

The gauze recommended by MacArthur[431] as being sufficient to exclude *Stegomyia fasciata* from buildings was of 14 mesh and 30 I S W G which gives an aperture of 0 0590 inch Le Prince and Orenstein[34] found that an aperture of 0 0485 inch would permit the passage of this species only under stress of circum stances whilst an aperture of 0 046 inch would exclude them altogether Tarle[473] states that in Porto Rico a mesh of 16 with a diameter of wire of 0 009 or 0 010 inch (aperture 0 05?5–0 0530 inch) will keep out practically all mosquitoes whilst a mesh of 14 with a diameter of wire of 0 015 inch (aperture 0 056 inch) is sufficient for most places Although other observers have carried out experiments with various types of gauze they almost invariably neglect to state the one essential point viz the size of aperture Further research on this subject is urgently required

The gauze used in the barracks of British troops in India is of 14 mesh and 28 30 S W G giving an aperture of 0 055 to 0 057 inch The standard adopted by the Punjab Government Public Works Department is of 12 mesh and 25 S W G giving an aperture of 0 063 inch The size of aperture recommended by Messrs Christie Ltd of Glasgow for the screening of houses is 0 0408 inch (18 mesh and 28 I S W G) This gives a ventilation area of 53 93 per cent as compared with 68 23 per cent given by a gauze of 14 mesh and 30 I S W G

(ii) *Strength of Wire* —It is obvious that other things being equal the greater the diameter of the wire used the stronger will be the gauze It is equally obvious however that the use of a thicker wire will mean the exclusion of more air and light Our aim therefore should be to obtain the thinnest wire which will give the required strength *The gauge usually recommended is* 28–30 I S W G denoting a diameter of 0 0148 to 0 0124 inch or 28–30 S W G denoting a diameter of 0 016 to 0 014 inch In order to obtain the greatest amount of air and daylight a

heavier gauze may be used in places subject to the greatest amount of wear, such as doors and the lower half of verandah screens, etc, a lighter type being employed for less exposed situations

(iii) *Durability of Screen* —The material of which the gauze is made is of great importance Painted* steel or galvanized iron wire are the cheapest, but are not suitable except in a very dry climate Darling[334] found that in a warm moist atmosphere galvanized iron and brass screening corroded rapidly whilst copper and phosphorized bronze both resisted deterioration admirably When tested in a salt laden atmosphere the copper screening also became badly corroded, the bronze resisting to a much greater degree He therefore concluded that phosphorized bronze was best for places near the sea, but that for other places in the tropics the less expensive copper screening was just as effective, provided the copper content was high (about 90 per cent), and the amount of iron as low as possible (not more than ½ per cent)

MacArthur[481] recommends the use of 'Monel metal' as being the best for use in a moist climate This consists of nickel 57 per cent, copper 28 per cent other metal 5 per cent It is a natural alloy of metals, and contains no tin zinc or antimony A disadvantage of this is its high cost Earle[473] states that in Porto Rico the only two kinds of wire which have been found durable are of Monel metal, diameter 0 009–0 010 inch and of copper or bronze diameter 0 015 inch

Wurtz[492] recommended the use of ordinary cotton netting, treated with a solution of commercial silicate of potassium in its own volume of water This is painted on several times with a brush, without drying between the coats and is said to make the cotton much stronger and more resistant to water or fire

The gauze now being tried in the British troops' barracks in India is composed of copper 90 per cent, and tin 10 per cent

* It should be noted that painting reduces the size of the aperture.

The essential requirement for screening is that the wor should be thoroughly carried out Frequent inspection is necessary for the detection of rents in the wire and defects in the wooden framewor] the latter being especially likely to develop where there is extreme variation in humidity between the dry and wet seasons

(See *Bibliography* Nos 468–493)

PART II.

MEASURES DIRECTED AGAINST ADULT MOSQUITOES.

1. Destruction by Hand.—This method has received increasing attention in recent years, and in view of the fact that recently fed and therefore possibly infected mosquitoes may be killed in this way it has an important bearing in the prevention of malaria Children may be taught to use the methods enumerated below and Ross[37] has suggested that the offer of one anna for 50 anophelines would probably result in a very extensive catch in any village

(*a*) *Hand nets* may be made cheaply by tying a piece of flexible cane or wire in the form of a loop to which a bag of white netting about 18 inches deep is attached In lofty rooms a long handled net may be used

(*b*) *Swatters* consisting of a piece of wire gauze about 6 inches square fixed to a two foot wooden handle may be used and are especially effective on wire screens

(*c*) *A chloroform tube* 7 inches long by 1 inch in diameter may be used A layer of rubber bands or pieces of old tyres one inch thick is placed in the bottom of the tube held in place by a plug of absorbent cotton covered with a disc of blotting paper or cork A few c c of chloroform are poured in and are absorbed by the rubber This will last for two or three weeks A test tube with a plug of cotton wool soaked in benzene or petrol may also be used or a test tube wetted inside with kerosene To catch the mosquito remove the cork and place the mouth of the tube quickly over the insect as it rests on some object An electric torch is a great assistance

(*d*) *A tin* with some petrol or kerosene in the bottom, fixed to the end of a long stick, is useful in catching mosquitoes on ceilings

(*e*) Curtains etc, may be shaken and the mosquitoes flying out caught by hand if the latter is first dipped in soapy water

The above methods may be used to supplement screening

2. Traps.—The use of traps for catching mosquitoes was suggested by Nuttall and Shipley[517] in 1902, as the result of their experiments to ascertain the colour most attractive to mosquitoes * Various different forms of trap have been devised, several of which are described below

Traps are used for three chief purposes, (*i*) for reducing the number of mosquitoes (*ii*) to find out the relative prevalence of *the different species of mosquitoes and (iii) in order to gauge* the effect of control measures In the last two cases the traps are placed in various quarters of the area under observation and counts are made of the mosquitoes captured in each trap daily This is a valuable method for estimating the efficiency of anti larval measures and an increase in the catch in any particular locality will often lead to the detection of some breeding place which would otherwise be overlooked

Traps may be used either inside or outside buildings James' trap[273] was designed for use in the shaded corner of a garden, and Zetek[571] recorded that in camps where traps were placed on the leeside of buildings a large number of anophelines were caught, resulting in a reduction in the incidence of malaria

When used inside houses barracks etc, the success of traps largely depends on the type of building in which they are employed In well built barracks with whitewashed walls the proportion of mosquitoes caught will be considerable because the traps form a more attractive resting place than the bare white

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* These observers found that dark blue was the most attractive colour, and it is suggested that this would probably be the most effective colour to use for the inside of the traps here described

walls But in ill lighted, 'kuchcha' built buildings where there are many dark corners, crannies in the walls, etc providing suitable resting places for mosquitoes only a small proportion of these insects will be found in the traps The placing of baits in traps (excepting human baits see p 18), has not been attended with success * and in those described below the object aimed at has been merely to provide an attractive resting place for mosquitoes

(*a*) *Lefroy's Trap*[513] —This is a wooden box 12 inches long by 12 inches wide and 9 inches deep lined with dark green baize and having a hinged door The floor of the box is covered with tin The trap is set in a dark corner at night and in the morning the door is closed and the insects killed by dropping a teaspoonful of benzene or chloroform through a small hole in the top of the box fitted with a movable plate

(*b*) *Fletcher's Trap*[511] —This consists of a wooden skeleton of a box with a hinged lid covered on all sides with black mosquito netting This is contained inside an open topped wooden box, painted black inside The whole is placed in a suitable position *at night with the hinged top of the inner box open In the* morning the lid is closed with a metal hook fastener and the inner box lifted out by handles provided for the purpose The mosquitoes may be killed by placing this on the bare ground in full sunlight

(*c*) *Richmond and Mendis Traps*[238] —These observers have made a number of experiments with various traps of their own device in barracks The most successful of these were —

(i) *The Crinoline Trap* A skirt' of navy blue or black cloth with an upper opening 4 inches in diameter (which can be closed with a purse string) is suspended from the roof about 6 feet above the floor level A bamboo hoop 3 feet in diameter is attached to the inside of the skirt 2½ feet from the top, and below

* Meta' ' has suggested the employment of small *pig styes as traps for out*side use (*see* 'Zooprophylaxis')

the hoop the skirt is continued in the form of a fringe hanging vertically downward for a distance of 3 feet The lower opening can be closed by a purse string, which runs through loops round the *outside* of the skirt (Fig 3) At night the upper opening is closed, whilst the lower is left open In the morning the lower opening is closed, and an inverted glass jam jar is inserted into the upper one The trap itself is *then well shaken with the result that the imprisoned* insects fly upwards towards the light into the jar, and can be removed alive

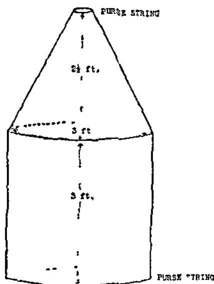


FIG 3
Crinoline trap (after Richmond and Mendis[224])

If living mosquitoes are not required, the insects may be killed by simply spraying them with 'Flit' or other spray, without previously closing the lower opening

(ii) *Box Traps* —These are made of wood, 3 feet by 2 feet by 2 feet, lined inside with black cloth, open at the

end with no door but fitted with a detachable black muslin lining with a purse string at the open end. This lining is provided with loops which slip over hooks inside the box. The purse string is closed in the morning when the sleeve may be detached and the insects removed alive if desired.

(iii) *Wire Traps*.—These are of the same dimensions as the box traps but consist of 4 strong wire frames which can be joined together with string to form the framework of the trap. A black cloth covering is slipped over this and a detachable sleeve (as described above) attached inside. The advantage of this type over the box trap is its easy portability which makes it particularly suitable for field service conditions.

Of the three forms of trap described above Richmond and Mendis found the box and wire traps the most effective. One trap to each 5 000 cubic feet of space in a well built British barrack room with a capacity of 20 000 cubic feet captured 60 to 65 per cent of the anophelines present. The traps were placed 2 or 3 feet above the level of the floor.

(*d*) *Sergent's Trap*.—This is a portable wooden trap described by Legroux[23] and stated by him to have been designed by Dr Etienne Sergent. One end of the trap is smaller than the other and at this end there is a gauze door overhung by a continuation of the roof of the trap (Fig 4). The door is left open at night and is closed in the morning. At the larger end of the trap there is a gauze-covered window with a wooden shutter. By opening the shutter the catch can be viewed and counted.

(*e*) *Proudlock's Traps*. These are ingeniously devised patent traps made in two principal types.

(i) *The Household Type* for use in bungalows etc consists of a small wooden box painted black inside with a vertical entrance in front fitted with a

shutter, and a sliding panel at the back When the latter is opened a glass window is disclosed through which the catch may be viewed When this is exposed to sunlight the insects are quickly killed and may be emptied out through a small hole at the side of the trap fitted with a shutter

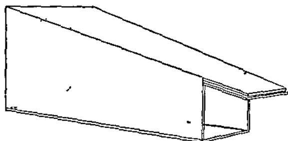


FIG 4

Sergent s trap (after Legroux[230]) The gauze door in front is opened to allow mosqu toes to enter The shutter over the circular ga ze covered window at the back is closed

(ii) *The Research Type* is a more elaborate trap consisting of an elongated box with a funnel at one end through which the mosquitoes enter At the rear end at the side of the box there is a small opening with a shutter over which can be fitted a slide rather like the plate holder of a camera but with a glass face In the morning a plunger is inserted at the front end of the box and the shutter at the rear end opened together with a corresponding shutter in the slide The plunger is then pushed home and the mosquitoes are driven into the slide box which can then be removed

(*f*) *Clemesha s Trap* —This is an ordinary tea plucking basket, plastered inside and out with cowdung and covered with a lid, also plastered in which there is a central opening 6 inches in diameter The trap is hung up a little above the floor in a

cowshed or other building with some grass or hay in the bottom The catch is collected by first closing the opening in the lid and then placing the trap under a mosquito net The operator enters the net, opens the lid and shakes the trap, the mosquitoes being caught in test tubes on the inside of the net

(g) *Strickland and Choudhury's Trap*[519] —This is made from a tea box, 18 inches by 18 inches by 18 inches, blackened inside, and with a circular hole in the side which can be closed by means of a swivelled door Strickland and Chowdhury recorded better results with this trap than with Clemesha's trap

(h) *James' Trap*[°"3] —A rectangular wooden framework, 5 feet by 3 feet by 3 feet, is covered with mosquito netting, one end of it being a door on hinges The trap is placed on the ground in a shaded corner of a garden and covered with sacking and a thick *tarpaulin, so that the interior is dark and cool Two or three* plants are placed inside each trap and several near the door, which is left partly open at night At about 8 or 9 a m, the vegetation round is disturbed as much as possible, and straw and paper torches are burnt in all the surrounding outhouses and buildings to drive out the mosquitoes, most of which take shelter in the trap About half an hour later the door of the trap is closed, the sacking and tarpaulin removed and the trap placed in strong sunlight for one or two hours when all the mosquitoes are killed

(i) *Chatti Traps* —These are the ordinary earthenware water vessels commonly used in tropical countries They are half filled with water, and placed in corners of buildings Mosquitoes may be collected from them by means of a cylindrical frame covered with gauze, which is continued upwards in the form of a sleeve They are useful for catching culicines but are ineffective for anophelines

(j) *Traps on Screens* —These are essentially labyrinths of wire gauze on wooden frameworks, which are fixed on to the inside or outside of screens of buildings. Most mosquitoes are caught while trying to get in The traps act automatically, and need only be emptied at long intervals They have been used with great success in Panama[34]

McHardy[515] in Dar es Salaam has devised a 'trap house' with these traps fixed on the wire gauze which screens it The trap house is made in sections, so that it can be easily taken down and erected wherever desired African natives sleep inside it acting as a bait'

(k) *Trap holes*—Blin[510] described experiments in which he dug oblique holes in the ground near houses infested with mosquitoes The insects which came to rest in them to seek darkness and protection from the heat were destroyed in the daytime with a torch made with a wisp of straw or a stick dipped in kerosene

(l) *Illuminated Traps* have been used in the U S A with considerable success (Owen[518], Headlee[512]) Certain species of mosquitoes are attracted by a moderate light, though if the light be too strong it repels them The trap used by Headlee is fashioned from a sugar tin, 12 inches high and 10 to 12 inches in diameter, with the bottom removed and replaced by a cone of wire gauze, which projects into its interior There is an opening not more than ¼ inch in diameter at the summit of the cone Light is supplied by a small electric bulb connected with a battery

(See *Bibliography*, Nos 510–521)

3. Fumigation.—Whichever method is used all chinks in the doors and windows should first be closed by hanging blankets over them It is best to leave one window uncovered and to darken all the others A white sheet is placed on the floor in front of the uncovered window The reason for this is that in most cases mosquitoes are not killed by fumigation, but are only stupefied They will for the most part fall on the sheet, and can then easily be seen, swept up and burnt

(a) *Pyrethrum Powder* (*Pyrethri flores*) *—This is made from the dried flower heads of the chrysanthemum (*Pyrethrum cinerariaefolium*) It forms the main ingredient of

* This must not be confused with *Pyrethri radix* (pellitory root), which has also been recommended as a fumigant

many insect powders, e g, 'Keating's Powder,' and owes its insecticidal activity to a mixture of acids and esters It also contains oleoresins to which it probably owes its value as a fumigant and since these are volatile it is essential that the powder *shall be fresh It is also important to ensure that it* is not adulterated with the powdered stems of the plant, which is a common practice

The powder may be used dry and puffed or blown into the air of a room For fumigation it is heaped up in an iron pot into a little pyramid, which is lighted at the top and burns slowly, giving off a dense and pungent smoke A layer of sawdust 2 to 3 inches deep placed in the bottom of the pot in the form of a crater permits complete combustion thus saving 10 to 15 per cent of the fumigant which would otherwise be wasted The powder may also be moistened and made up into small cones which burn readily when dry One pound at least is necessary for 1,000 cubic feet of space (Boyce[3] recommends 3 lbs) The room should be kept closed for a period of 3 hours

Other methods are to heat the powder on a metal plate over a kerosene lamp or to puff it from an insufflator into a burning gas jet The fumes are not noxious to human beings

(b) *Sulphur Dioxide*—This may be applied in various ways

(i) For operations on a large scale the use of a Clayton machine has proved most effective for destroying mosquitoes in yellow fever epidemics Various types of Clayton machine are on the market At Accra a machine mounted on a bogie carriage is always kept ready for action For treating ships, the machines are installed in special boats There is also a light type of Clayton machine which can be carried by two men, it is air-cooled, and is capable of saturating 6 000 cubic feet of space per *hour with a 15 per cent strength of gas* (Parsons and Brook[236])

McHardy[515] in Dar es Salaam has devised a 'trap house' with these traps fixed on the wire gauze which screens it The trap house is made in sections so that it can be easily taken down and erected wherever desired African natives sleep inside it, acting as a 'bait'

(*k*) *Trap holes* —Blin[510] described experiments in which he dug oblique holes in the ground near houses infested with mosquitoes The insects which came to rest in them to seek darkness and protection from the heat were destroyed in the daytime with a torch made with a wisp of straw or a stick dipped in kerosene

(*l*) *Illuminated Traps* have been used in the U S A with considerable success (Owen[518], Headlee[512]) Certain species of mosquitoes are attracted by a moderate light, though if the light be too strong it repels them The trap used by Headlee is fashioned from a sugar tin 12 inches high and 10 to 12 inches in diameter, with the bottom removed and replaced by a cone of wire gauze, which projects into its interior There is an opening not more than ¼ inch in diameter at the summit of the cone Light is supplied by a small electric bulb connected with a battery

(See *Bibliography*, Nos 510–521)

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(c) *Cresylic Acid Derivatives*—

(i) *Cresol Vapour*—This is probably the cheapest fumigant Four to five ounces of Liq cresol sap are required per 1 000 cubic feet It may be slowly vaporized over a kerosene stove of the 'Beatrice' type (in which the flame is guarded by a metal chimney with a mica window) the cresol being placed in some enamelled receptacle which should completely cover the grating on which it rests the receptacle should be as large and deep as possible so long as its position is secure Constant observation is necessary and a bucket of water should be at hand in case the cresol should catch fire The stove can be put out usually in about half an hour s time (the time varies according to the size of the room and the amount of cresol used) after which the room should be closed for another 1½ to 2 hours It may also be evaporated in kerosene tins over charcoal braziers The braziers should be glowing when put into a room otherwise the fumes given off are liable to blacken the walls and furniture Richmond and Mendis[238] found that the cost of fumigating with cresol vapour including the price of the charcoal used was 1 65 annas per 1 000 cubic feet Another method of vaporizing cresol is to ignite dung cakes and pour the cresol over them when half burnt

Although the cost of cresol fumigation is so low the amount of preparation and precautions required for its use are much greater than in the case of sulphur Opinions differ as to the relative efficiency of the two methods Richmond and Mendis consider sulphur fumigation to be the more satisfactory though the cost (about 3½ annas per 1 000 cubic feet of space) is more than twice as great as with cresol Hanafin * on the other hand considers cresol to be the more effective and has obtained excellent results

* Private communication

(ii) It may be applied in the form of 'Sulphume,' a proprietary preparation of liquid sulphur dioxide put up in metal cylinders holding about 20 ozs This was however not found very effective in a single experiment conducted by Parsons and Brook[236]

(iii) Sulphur may be placed in an iron pot, and this placed on bricks in a tub or other receptacle containing an inch of water in the bottom It is readily ignited by sprinkling methylated spirit or kerosene over it and lighting it It is usually stated that 2 lbs of sulphur should be burnt for 1 000 cubic feet of space with exposure to the fumes for 2 to 3 hours (but *see* below)

(iv) *Giles Sulphur Cones* —These consist of one part each of nitre and charcoal to eight of sulphur made up into pastilles weighing 4 ozs each by means of a little gum water and dried in the sun Giles'[6] recommended that one pastille should be burnt for every 1 000 cubic feet of space but this would only be equivalent to 3 2 ozs of sulphur Richmond and Mendis'[38] found that 4 pastilles (12 8 ozs of sulphur) were effective in barracks for every 1 000 cubic feet of space whilst for fumigating tents 6 pastilles (19 2 ozs of sulphur) were required per 1 000 cubic feet Even this amount, however, is much less than the quantity of sulphur specified by other authors as necessary

Richmond and Mendis[238] found the use of Giles' cones a very convenient method for sulphur fumigation They are placed on tin plates on the floor, and when lighted burn quickly, producing a maximum concentration of sulphur fumes in a very short time

A great disadvantage of sulphur is that it tarnishes metal work and injures pianos sewing machines watches telephones, etc It is also harmful to food stuffs

destructor of mosquitoes but its use is attended with too much risk to make it suitable for general use[236]

(*g*) *Mercuric Chloride* has been used by Guiteras[238] in America sublimated in a porcelain dish over an alcohol lamp He used 25 gm to 1 000 cubic feet of space allowing it to act for 2 to 3 hours He claimed that its poisonous qualities do not constitute a real danger that it is very simple and effective and requires very little apparatus

(*h*) *Waste Tobacco* has been used with effect in Russia[237] mixed with chopped hay or straw and burnt on iron sheets It is left to smoulder for 16 hours and 30–40 gm are required per cubic metre of space

(*i*) *Smoke Production* —The principle of this measure is to fill the building with smoke quickly to drive mosquitoes out of holes and corners and to attract them to one spot where they can be destroyed The doorway is covered with a white sheet made as taut as possible A pile of dry straw is lighted and then covered with damp straw or manure When the smoke fills the building the insects fly to the sheet where they can be killed[239]

(*j*) *Datura stramonium* in powder may be used (8 ozs to 1 000 cubic feet) made up with nitre or saltpetre in the proportion of 1 to 3 of datura The mixture may be burnt on a tin pan or shovel Smith[241] states that the fumes are not poisonous to human beings are not injurious to fabrics or metals and can be used with entire safety

Many other substances have been tried as fumigants such as chloral vapour dried orange peel *Artemisia* (*santonica*) pastilles of pellitory root (*Pyrethri radix* the dried root of *Anacyclus pyrethrum*) dinitrocresol etc

The relative merits of fumigation and spraying are discussed on p 25

(See *Bibliography* Nos 218 241)

4 Sprays —Experiments with various sprays as destructors of mosquitoes were carried out by Giemsa and Muhlens[500] in 1911 following the appearance of an article by Stendel[508] who called

with it in Lahore No precaution was taken to seal up the rooms treated beyond closing the doors and windows

(ii) *Cresol and Lysol* —A mixture of equal parts of these was used by Parsons and Brook[236] with satisfactory results

(iii) *Creolin and Izal* —Alexander[218] in Accra made various experiments with these preparations Creolin was first used then a mixture of creolin and izal and finally izal alone the latter proving very satisfactory It was found necessary to use enamelled receptacles otherwise soot was deposited The technique is similar to that for cresol

(d) *Camphor and Carbolic Acid (Mimm's Culicide')* — Equal parts of camphor and crystallized carbolic acid are fused together into a liquid by gentle heat Three to four ounces of the mixture must be vaporized for each 1 000 cubic feet of space This is done by placing the liquid in a wide shallow pan over a spirit or petroleum lamp when white fumes are given off To prevent the mixture from burning the fumes should not be allowed to come into close contact with the flame of the lamp The room must be kept closed for two hours The vapour is not dangerous to human life except when very dense but it produces a headache if too freely breathed[94]

(e) *Formic Acid* —If commercial formalin (40 per cent formic aldehyde) and potassium permanganate are brought together, formic acid fumes are liberated which are toxic to mosquitoes For 1 000 cubic feet of space 10 ozs of potassium permanganate crystals are placed in a bucket containing 1 to 2 pints of water and 1 pint of formalin is poured into it An advantage of this method is that no heating apparatus is required so that there is no danger of fire, also there is no ill effect on furniture[236]

(f) *Chlorine Gas* —This may be applied from cylinders containing liquid chlorine or may be generated by pouring crude sulphuric *acid on to chloride of lime It is a powerful rapid and economical*

and petroleum ether They did not confirm the results of Brug and Van Slooten, as they found that in the case of all their experimental preparations a large proportion of the insects recovered after some hours in the fresh air, whereas with the proprietary preparations this was not the case

The cost of these preparations however, is so high that it would appear best to use a locally prepared mixture on the lines of that recommended by Brug and Van Slooten the mosquitoes stupefied by the spray being swept up and burnt immediately afterwards One such preparation has been used with success by Mansell[507] in Peshawar (formula No 6) Sprays of this nature should not be used in the vicinity of naked lights For small rooms they may be applied by means of the hand sprayers or atomisers which are now obtainable almost everywhere at a trifling cost For larger buildings such as barracks high pressure sprayers, such as the 'Four Oaks' Sprayer, have been used with success, though in the very lofty barracks usually built in the tropics it is sometimes found difficult to secure effective results

As regards the relative merits of fumigation and spraying, the latter would appear to offer many advantages James,* working with artificially infected *A maculipennis* arrived at the conclusion that infected anophelines usually pass their whole life in the house where the infection occurred If this were of universal application, fumigation or spraying even at long intervals would appear to be an effective means of controlling malaria Subsequent investigations by many workers in different parts of the world have however shown that there is normally a very considerable to and fro movement of anopheles in and out of buildings, and that even shortly after a blood meal anopheles may change their abode (Kligler and Liebman[545], Richmond and Mendis[738], and others) Either method therefore to be successful must be repeated at frequent intervals (every 3 or 4 days) and in the case of fumigation the necessity for evacuating rooms or barracks

* *Trans Roy Soc Trop Med and Hyg*, XX, p 143 (1926)

attention to the neglect of this method of malaria prevention Mixtures containing cresol and phenol were found too irritating to the human respiratory tract, and the same objection applied to solutions of quassin Finally Giemsa evolved a mixture containing pyrethrum tincture, soft soap and glycerin, which constituted an effective spray free from the above objections (*see* formula No 1 below) The pyrethrum tincture was however expensive, and Giemsa[503] conducted further experiments to find a cheaper spray He found that soap solutions alone gave good results and that *the toxic properties of a number of other* substances besides pyrethrum were enhanced by the addition of comparatively small quantities of soap He recommended the use of soap solutions containing formaldehyde as being both cheap and effective

In recent years a large number of proprietary sprays have been put on the market, most of them having a basis of kerosene oil The following may be mentioned —Flit, Flytox, Mosquil, Shell tox, Whiz, Flyosan, Fly ded, Necrosene Rids, Alio Spree, and Abis Richmond and Mendis[738], experimenting with Flit Mosquil kerosene and Army Fly Spray, found Flit the most effective but *considered that the somewhat greater success* attained with this preparation, compared with Mosquil and kerosene, was scarcely worth the extra cost Mosquil was more effective than kerosene, but four times as costly, whilst Army Fly Spray (formula No 3) was not satisfactory

Brug and Van Slooten[497] found that a mixture of kerosene with 2 per cent of carbon tetrachloride was effective, and was superior to Flit in that it did not produce stains on white fabrics *This gave as good results as a mixture which they termed* 'Rids locally prepared' (formula No 5)

Swellengrebel and his co workers[303] carried out experiments with various proprietary sprays, and with a large number of experimental preparations consisting of kerosene oil with the addition of small proportions of carbon tetrachloride, methyl salicylate, turpentine, creosote, oil of cajaput, aniline oil, petrol

(5) *Rids locally prepared* (Brug and Van Slooten)—

Kerosene o l	89 6
Carbon tetrachloride	7
Methyl sal cylate	3 4

(6) *Mans ll s Spray*—

Carbon tetrachloride (med cinally p ire)	1
Synthet c o l of w ntergreen	2
Kerosene o l nd qual ty	97
Naphthalene	½ lb per gall

(See *Bibliography* Nos 494–509)

5 Cutting down of Jungle and Other Vegetation — Many species of anophelines spend the daytime sheltering amongst long grass or in bushes and other coarse vegetation and the clearing away of these in the vicinity of dwellings is therefore of value in the campaign against adult mosquitoes (*see* also p 35)

6 Cultivation of Alleged Deterrent Trees and Plants — Eucalyptus trees nim trees chinaberry trees castor oil plants papava lavender clover and various aquatic plants have been said to have a deterrent effect on mosquitoes but experiments have proved that none of them have any direct effect against adults

d Herelle[138] seeking to explain the relative immunity from malaria of certain tracts of country (Tuscany Argentina Holland) in spite of the presence of anopheline mosquitoes noted that clover was grown in such countries and suggested that coumarin ingested by the female insect from the clover might have an effect on the malaria parasite harboured by it comparable with that which quinine has on the parasite in man

Willcocks[154] quoted d Herelle s remarks and suggested that the relative immunity of cultivated Egypt from malaria might likewise be due to the presence of clover He advocated the introduction of clover and other leguminous plants and trees into Palestine Cyprus Irak Northern India the Sudan and Uganda His paper was widely commented on by the lay press

for periods of several hours makes the prosecution of an effective campaign difficult or impossible. Moreover with sulphur dioxide the tarnishing of metals and injury to watches etc constitute a great drawback which renders the procedure most unpopular among troops. With sprays the whole operation can be performed in a very short time without the necessity of removing any of the contents of the building and the rooms can be re occupied within half an hour of spraying. Another advantage of spraying is that it is also effective against sandflies on which fumigation appears to have but little effect[238]. Spraying may be used with advantage to supplement screening.

The formulæ of various sprays are given below —

	Parts
(1) *Giemsa's Spray—*	
Pyrethrum tincture (20 parts pyrethrum extracted in 100 parts methylated spirits)	580
Potash soap	180
Glycerin	240

The above mixture to be diluted with 20 volumes of water before use. 100 grammes of the fluid suffice for 50 cubic metres of space.

(2) *Lefroy's Spray—*	lbs
Pyrethrum	2
	gall
Alcohol	1
Safrol	1
Soap	q s to form an emulsion (usually about 10 ozs)

In hot climates add ½ to 2 per cent castor oil. Dilute one in 30 before use.

	Parts
(3) *Army Fly Spray—*	
Pulvis pyrethrum	117
Spirit rectificatus	912 (or q s)
Camphor oil	780
Sapo durus pulvis	2 37
(4) *Brug and Van Slooten's Spray—*	
Kerosene oil	100
Carbon tetrachloride	2

could not be induced to live in the roosts Nelson[51] has pointed out that bats are of little value against mosquitoes, their chief food consisting of other insects It is generally recognized that the employment of these creatures is not likely to prove of practical utility in mosquito control

(See *Bibliography*, Nos 48–54)

8. Zooprophylaxis.—Animal prophylaxis against malaria was suggested by Roubaud[554] in 1919, although Rizzi[553] claims that this method of protection was first recognized and practised in Italy Roubaud pointed out that *A maculipennis* only feeds on man in the absence of other sources of mammalian blood and suggested that man could have complete protection from the attacks of this species by keeping cattle in the proximity of human dwellings He stated that in regions where cattle were plentiful a race of these mosquitoes has evolved which have adapted themselves to feed exclusively on animals Other authors have pointed out that whilst the presence of cattle may attract mosquitoes to themselves, the total population of anophelines in a locality is largely increased where cattle are plentiful There are also other factors to be considered, one being that the presence of large numbers of cattle goes hand in hand with increased agricultural prosperity, better drainage, clearing of jungle and a betterment of the social and economic condition of the population all of which may tend to diminish the incidence of malaria It may further be pointed out that the presence of anophelines in a cowshed does not necessarily mean that these have fed on the cattle occupying it Numerous experiments by means of the precipitin test have shown how frequent it is to find human blood in mosquitoes caught in cattle byres, stables, etc and, conversely to find the blood of cattle and other domestic animals in those captured in human habitations

Symes[565] records that in Taveta, Kenya Colony, the women and children have for years lived in huts together with their cattle The parasite rate is 50–60 per cent and the spleen rate 85 100 per cent, whilst it is usual to find the majority of the malaria-carrying

Mayne[148] carried out laboratory tests with coumarin and various species of Indian anophelines, and concluded (1) that coumarin did not exert any deleterious effect on the lives of the mosquitoes feeding on it, and (2) that coumarin, taken with the liquid extracted from a clover blossom, would have no deleterious action on oocysts and sporozoites undergoing development in the infected mosquito

There is no definite proof that clover has any effect on the incidence of malaria, and the only recorded experiments which have been carried out as to the effect of coumarin on mosquitoes or malaria parasites indicate that it has no effect on either under natural conditions

The planting of certain trees and plants, however, has a good effect by drying up water and reducing the level of the subsoil water Amongst others which have been recommended in India for this purpose are —Pines, Casuarina, Nim, Eucalyptus, Sun flower, Canna Castor oil plant, Chrysanthemum

The planting of belts of *high* trees* as a screen against the diffusion of mosquitoes is a measure of practical importance, and it is an advantage to have a screen of forest between breeding places and human habitations If such a natural defence exists it should on no account be removed, as has been done on occasions with disastrous results †

(See *Bibliography*, Nos 124–151)

7. The Use of Bats as Mosquito-destroyers.—That bats destroyed mosquitoes has been known for centuries, and the fact was mentioned by Pliny in his work on natural history Campbell[149] in 1909 built a bat roost at San Antonio, Texas, the object being to breed bats which would destroy the local mosquitoes and would also prove a paying proposition on account of the production of guano Subsequently the experiment was repeated in Italy, but without success the chief difficulty being that the bats

* As distinct from low jungle or scrub

† The question of planting shade giving trees and plants as an anti larval measure is discussed later (p 36)

PART III.

MEASURES DIRECTED AGAINST THE LARVÆ OF MOSQUITOES.

A.—DESCRIPTION OF METHODS USED

Before describing the methods employed in dealing with arvæ, it is necessary to point out the extreme importance of a areful preliminary survey of the area in question so that it may e ascertained which species of anophelines are present, and where he breeding places of each are situated Attention may thus be oncentrated on measures to deal with the breeding places of the rincipal malaria carriers For example, it is worse than useless o embark on expensive measures to drain a collection of water hat may be harbouring either no larvæ at all or only those of armless mosquitoes whilst the less obvious breeding places of he malaria carriers are overlooked

Attention is also drawn to the fact that, when the favourite reeding places of any particular species have been eliminated, it will tend to breed in other situations so that careful periodical inspections of the area concerned are essential

A point of great practical importance is the extent of the area over which it is necessary to practice anti larval measures No strict rules can be laid down on this point, for a great number of factors must be taken into consideration, and the final decision will depend on a close study of the local conditions prevailing, such as the species of malaria carrying anophelines concerned, the intensity of breeding, the direction of the prevailing wind, etc

As a general rule, in India, anti larval measures should be undertaken for a distance of at least half a mile from the periphery

anophelines close to the sleeping place of the human beings, in spite of the proximity of the fire, and the much greater accessibility of the cattle He considers that the presence of the cattle in this region gives very little protection

In India especially in the Punjab, a season of heavy rainfall following a year of drought is frequently the precursor of an out break of malaria in epidemic form Cragg[578] has suggested that since the number of cattle which normally form a protection to the population is decreased in proportion to the severity of the preceding drought whilst the number of anophelines is increased by the heavy rains, this may be an important factor in the genesis of these epidemics He further suggested that the great extension of irrigation works primarily intended as a protection against famine, may prove to be in itself a great anti malarial measure for *with an assured supply of water there will be sufficient fodder to* keep the cattle alive in times of drought

Close association with cattle does not always prevent an epidemic of malaria In the Punjab epidemic of 1908 the cattle zone of Amritsar city was one of the worst epidemic areas Fry[540] *however points out that though those living in this zone suffered* owing to the presence of cattle the rest of the town was probably protected thereby from the abnormal mosquito population He suggests that if cattle sheds were arranged on the outskirts of a village instead of indiscriminately as is usually the case, the inhabitants would be more free from the attacks of mosquitoes

Fermi[538] states that if animal prophylaxis is to be effective the cattle sheds should be situated at a distance of 50 to 100 yards from human dwellings

A very large amount of literature dealing with the subject of *zoophilism has appeared during the last 10 years* It is impossible *to include a complete bibliography, but references to a number of* the more important papers are given at the end of the book

(See *Bibliography,* Nos 522–567.)

this connection C J Wilson[50] as the result of experiments with a specially constructed trap made with mosquito netting in the Federated Malay States came to the conclusion that the result of trap catches was more valuable as an indication of the species of anophelines frequenting dwellings than the results of catches by collectors Out of 1 526 mosquitoes caught in the trap in some coolie lines in 12 nights 167 were anophelines of which 22 were *A maculatus* Two trained collectors searched in the lines each morning during the same period and caught 564 mosquitoes of which only 25 were anophelines and none were *A maculatus* *

A record is kept of the number of each species taken in each catching station This is a most valuable means of testing the efficiency of control measures and will frequently lead to the detection of some breeding place which would otherwise be over looked

After the usual preliminary malaria survey has been carried out the following procedure is suggested —

(i) First select catching stations one at least being situated on each side of the area to be protected Regular catching should preferably be started at least six weeks before the beginning of the malaria season Indeed it would be better still if catching and other observations could be carried out for one complete season before instituting control measures but this is seldom possible in practice

(ii) Institute rigid anti larval measures over all actual and potential breeding places of malaria carrying anophelines for a distance of one quarter of a mile from the periphery of the area to be protected Control measures should be initiated *before* the annual increase in the numbers of adult malaria carrying anophelines occurs i e usually about one month before the commencement of the malaria season

* The experiments here referred to were actually carried out by Mr B A R Gater the collector sleeping inside the trap

of the area to be controlled. This may have to be extended in certain directions if breeding of malaria carrying anophelines outside this radius is very intense or if there is a strong prevailing wind from a particular quarter. On the other hand it may not always be necessary to undertake rigid control measures for half a mile in *every* direction. Thus Senior White[83] obtained excellent results by instituting anti larval measures *for a quarter mile radius round* certain camps in a very malarious area in the Vizagapatam Agency (Madras Presidency, India) where a railway was being constructed, the area being extended in one direction nearly three quarters of a mile from the centre of the main camp on account of the prevailing wind.

On the other hand Hackett[418] in Italy has found it necessary to control mosquito breeding for a distance of 3 kilometres (nearly 2 *miles) from the periphery of the area requiring protection*. Evidently *A. maculipennis* is a stronger flier than most of the malaria carrying anophelines of India, with the possible exception of *A. sundaicus*.

Many experiments have been carried out with a view to ascertaining the distance of flight of anophelines and it has been shown that on occasions certain species will fly for distances of several miles. But in considering the size of the area over which it is necessary to practice anti larval measures it must be remembered, as Ross[37] has pointed out, that it is not a question of the power of flight of anophelines or how far they *can* fly but how far they actually *do fly on the average*.

In instituting control measures much useful information may be obtained by the use of "catching stations" or "observation stations". Certain shelters are selected in various quarters of the camp, village or other locality which is to be protected. These are visited regularly (daily if possible during the first season of control) and the same collector catches as many adult anophelines as possible in a *given time*, say 15 minutes, in each spot. Or traps may be placed in selected places and the catches collected daily. In

particular part of the area and attention can then be mainly directed to these special places

Temporary measures such as the application of paris green oil etc should be discontinued at the end of the usual period of the malaria season in the particular locality concerned To continue them after this date will merely in the author's opinion, result in a useless expenditure of labour and money

Other things being equal permanent measures i e the complete abolition of breeding places should be adopted wherever possible Temporary measures such as oiling etc should only be employed (*a*) when the cause of breeding is temporary (e g during the construction of docks railways etc) or (*b*) when the cost of permanent measures is prohibitive It may be remarked here that permanent measures although they may involve a greater initial outlay than those of a temporary nature frequently prove more economical in the long run owing to the constantly recurring expenses of the latter and the necessity for maintaining a large inspecting staff

1 Clearing of Jungle* or Scrub—This is of value in the following respects

(*a*) It removes the sheltering places of adult mosquitoes

(*b*) It promotes evaporation and therefore the drying up of collections of water

(*c*) It discloses breeding places which otherwise may be overlooked

A word of warning on this subject is however necessary Certain dangerous malaria carrying species of anophelines e g *A maculatus A minimus*† and *A ludlowi* prefer breeding places exposed to bright sunshine The indiscriminate clearing

* Considerable confusion has been caused in India in the use of the word jungle some authors alluding to forests of high trees by this term others to low bush or scrub It is used in the latter sense here

† This is the case in India but in the Philippine Islands *A minimus* is said to favour streams heavily shaded by bamboo (Mel lazis[93])

(iii) If any particularly dangerous breeding places such as a ravine stream or seepage outcrop exist between the quarter mile and half mile radius control these also

(iv) Scrutinize the daily records from the catching stations The capture of a considerable number of malaria carrying anophelines in any particular catching station may indicate that control measures must be extended in that direction beyond the half mile radius (probably in the direction from which the prevailing wind is blowing) or that some particular breeding place has been overlooked

(v) Wherever possible catching stations should also be instituted in some village in the neighbourhood where the conditions are as nearly as possible the same as in the area under control but where no anti malarial measures are being carried out A record should be kept of anopheline catches spleen rates morbidity and mortality rates etc in this village which may be compared with those observed in the controlled area It must be remembered that the incidence of malaria like that of other diseases may vary very considerably in different years and if no records are kept of an uncontrolled area as well as of the one where antimalarial measures have been instituted entirely erroneous conclusions may be reached as to the efficacy of the campaign The danger of over estimating the good effects of anti malaria measures is especially great because as a rule such measures are undertaken during the period immediately following an unusually severe malaria year when the incidence of the disease would in any case tend to become less

Our aim is of course to control the smallest possible area that will give good results Every hundred yards added to the radius of the controlled area means a large increase in expenditure It is usually found that expenses incurred in anti malaria measures during the first year can be very considerably reduced during subsequent malaria seasons It may for instance be found that all the malaria carrying anophelines are breeding in some

particular part of the area, and attention can then be mainly directed to these special places

Temporary measures, such as the application of paris green, oil, etc, should be discontinued at the end of the usual period of the malaria season in the particular locality concerned To continue them after this date will merely, in the author's opinion, result in a useless expenditure of labour and money

Other things being equal permanent measures, i e, the complete abolition of breeding places should be adopted wherever possible Temporary measures such as oiling etc, should only be employed (a) when the cause of breeding is temporary (e g, during the construction of docks railways etc), or (b) when the cost of permanent measures is prohibitive It may be remarked here that permanent measures although they may involve a greater initial outlay than those of a temporary nature frequently prove more economical in the long run, owing to the constantly recurring expenses of the latter and the necessity for maintaining a large inspecting staff

1. Clearing of Jungle* or Scrub—This is of value in the following respects –

(a) It removes the sheltering places of adult mosquitoes

(b) It promotes evaporation and therefore the drying up of collections of water

(c) It discloses breeding places which otherwise may be overlooked

A word of warning on this subject is however necessary Certain dangerous malaria carrying species of anophelines, e g, *A maculatus* *A.* *minimus*† and *A ludlowii*, prefer breeding places exposed to bright sunshine The indiscriminate clearing

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† This is the case in India, but in the Philippine Islands *A minimus* is said to favour streams heavily shaded by bamboo (Mieldazis[72])

of jungle in places where such species exist may therefore be followed by disastrous results This occurred in a district in the Federated Malay States where the wholesale clearing of jungle though proving inimical to the shade loving *A umbrosus* provided excellent breeding places for the more dangerous *A maculatus*

In Assam where *A minimus* is the principal malaria carrier an immense amount of harm has been caused by the clearing of jungle from the edges of streams and experiments are now being carried out with a view to finding the most suitable shade giving plants for use along the banks of streams in tea gardens For this purpose it is important that the plants and trees shall give *dense* shade and that they shall be evergreen It has been found that *durantha* (the thorny privet hedge) and *eupatorium* are suitable for narrow channels whilst for broader streams the jack fruit tree (*Artocarpus integrifolia*) appears to be efficacious (Ramsay[80])

The clearing of forests has also resulted in serious malaria epidemics in the high plateau region of Argentina where *A albitarsis A tarsimaculatus* and *A argyritarsis* all prefer sunlit water for their breeding places

2 Drainage —It is impossible to treat this large and important subject fully here Some of the chief points will be dealt with and for further details the reader is referred to the list of references given in the *Bibliography* under this heading

(*a*) *Open drains* —These should be narrow and deep rather than broad and shallow their banks should be kept clear of vegetation and sloped to an angle of about 45 degrees tributaries should enter at an acute angle or curve where possible and not at right angles in order to lessen the deposition of silt and débris at the point of junction The bottom of the drain should be rounded and not V shaped

In dealing with swampy areas drains may be made either parallel with one another or arranged in herring bone' fashion

The former method is the more economical For example in draining an area of 14 acres with lines of drains laid 100 feet apart, the herring bone system would require 300 feet more of drain than the parallel[181] (Fig 5) In British Guiana there is employed a method of making straight parallel drains and cultivating the intervening areas the plants grown taking up a large amount of water In the case of hill foot seepages the best method is to construct a system of contour drains to catch seepage at the point at which it arises (*see* p 89)

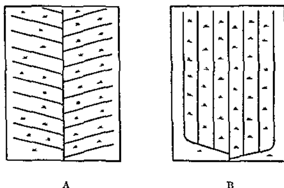


FIG 5

Two systems of laying out drains in areas of equal size In both the drains are the same distance apart but the length of drain in A is considerably greater than in B (after King[18])

Drains should be as few and as short as possible and the fall of the ground should be carefully considered before commencing work The excavation for drainage should start at the outfall end Sharp bends should be avoided wherever possible The main drain should be constructed first and the tributaries afterwards In some cases the use of dynamite has been found helpful in the construction of drains[195]

Open drains may be either pukka' i e lined with concrete, brick stone etc or 'kuchcha i e open earth drains A pukka

drain should never be constructed without first making a kuchcha one to determine the requisite depth of the drain and to see whether the flow is satisfactory

Pukka drains should be made with a central deeper channel or 'cunette' to take the water along quickly when its level is low and to minimize the extent of the breeding area At the point of junction with a side channel the opposite side of the drain should be strengthened and raised to prevent overflow 'Weep holes' should be made in the side of the drain so that the subsoil water may get into it These should slope downwards towards the bottom of the drain It is also an advantage to construct 'key walls' at right angles to the drain at intervals especially where there is a curve in its course to prevent water from outside tearing away the earth supporting the side walls (Fig 6) Key walls

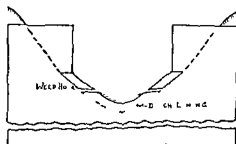


Fig 6
Cross section of key wall (after Le Prince)

should extend 6 inches to a foot or more into the ground below the bottom lining of the drain and in all cases weep holes should be provided just above the key wall In wide drains the side walls may be almost vertical

It is not always necessary to line the entire drain the lining of the bottom and sides up to 3 inches above the normal water line for small ditches being sufficient as a rule A drain may be roughly lined with flat stone, the interspaces being filled in with small stone

and sealed roughly with cement mortar Where flat stone is not available concrete made with gravel or small stone, in a layer of about 2 inches in thickness and reinforced with 2 inch mesh wire netting, may be used

In places where a drain has to pass beneath a road by means of a culvert, the grade of the drain should be increased, to prevent the accumulation of silt or débris The bottom of the culvert should be lined with stone or concrete A screen of vertical rods may be provided at the entrance of the pipe or culvert, and in the case of an earth drain the bottom should be lined for a distance of about 6 feet with flat stone or timber at the point of discharge, so as to prevent erosion and the formation of a pocket

In the case of kuchcha drains, if the flow of water is very swift undermining of the banks may occur, or if there is some temporary obstruction excessive local scouring may ensue removing soil from below the grade line of the bottom of the drain and causing a 'pot hole' Subsequently, if the rest of the drain becomes dry (as in storm water drains), pools will remain in such situations, which may become anopheline breeding places A small temporary channel should then be made to connect these pools and drain off the water It is sometimes possible to effect this rapidly in the case of a drain with a muddy bottom by dragging a small log downstream in its bed

The necessity for repeated re grading cleaning and oiling of open earth drains makes their upkeep expensive They are of no use in localities subject to very heavy rainfall as when this occurs the system will be wrecked Lined drains last much longer, are more easily cleaned require less inspection and are frequently ultimately less costly than open earth drains[184]

(*b*) *Subsoil drains* —The drain in this case is formed by a series of unjointed tile pipes laid end to end close together in trenches beneath the ground, the water entering from below at the points of junction of the pipes If soft spots are found in the bottom of the trench (which must of course be properly graded),

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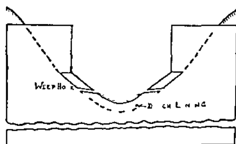


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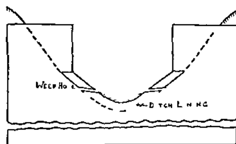


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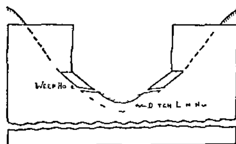


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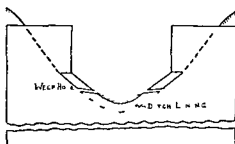


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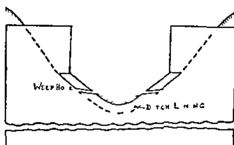


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(one fifth for main drains over 6 inches in diameter) during ordinary dry weather (at least 2 or 3 days after moderate rainfall) they will be sufficient to do their work during floods (Evans[168]) The pipes should be laid in an absolutely straight line with as few changes of gradient as possible

Greasy water and house waste must not be allowed to discharge into any part of the system Where pipes come near the surface proper bridge crossings are necessary to protect them from being crushed by carts etc The outlet of the subsoil drain must be well above the high water level of the stream lake or ditch into which it discharges Inspections should be made to see that the outlets do not become clogged with silt or other deposit Metal rods placed vertically at the outlet will prevent the entry of small animals which might die in the pipes and cause blockage

Subsoil drainage in connection with mosquito control is used for the following purposes —

(i) To lower the ground water so that pools of surface water will be more readily absorbed

(ii) To intercept seepage

(iii) To deal with hill streams in ravines

(i) Where this method is used for lowering the subsoil water the lines of pipes are usually spaced from 50 to 150 feet apart They are generally laid from 2 to 4 feet deep If laid nearer to the surface the water is drained away more rapidly but the area drained is less extensive The pipes are laid in the bottom of a perfectly graded narrow trench with their ends abutting one another closely and are then covered with clay or earth A grade of 1 foot or more per 400 feet is desirable[184]

(ii) To intercept seepage the drain is constructed above the line of outcrop at the time of maximum flow approximately at right angles to the flow deep enough to collect the seepage and with a grade of not less than 1 foot in 200 feet The pipes are laid with open joints or about one-eighth to one fourth inch apart and the trench filled with stones The uppermost layer should be

stones are rammed into place until a solid foundation is obtained Kligler[108] has found it useful where gravel is available to lay the tile pipe on about 10 cm depth of gravel and to cover it with 10–20 cm of the same material He has found that in pipes so laid clogging has been negligible whilst in others it is of periodic occurrence The laying of the pipes should be commenced at the outlet of the drain and continued upwards as the trench is made In fine easily disintegrated soils the pipe joints should be covered with a wrapping of canvas palm leaves or other material to prevent clogging The pipes should be of circular bore from 3 to 12 inches in diameter and 1 to 2 feet in length As a rule the internal diameter

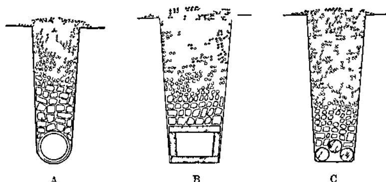


FIG 7

Cross section of three types of subsoil drains A Tile drain (after Le Prince[8]) B Stone drain C Pole drain

of the pipes should not be less than 4 inches even for hill foot drains whilst main drains are usually from 6 to 8 inches in diameter Where more capacity is required two or more drains may be laid side by side The thickness of the drain should be three eighths of an inch for pipes of 3 or 4 inches in diameter half an inch for those of 6 inches in diameter and five-eighths of an inch for those of 8 inches in diameter It is impossible to lay down rigid rules for the capacity of the system but in general it may be said that if the pipes are calculated to run not more than one quarter full

disadvantage is its cost, which is a grave objection, especially when dealing with ravine streams Senior White [8] remarks that in the case of streams which run only for two months or so after the slackening of the monsoon oiling is probably more economical

The cost of subsoil hill land drainage in and around the town of Kuala Lumpur, Federated Malay States was about £5 16*s* 0*d* per acre The cost of draining agricultural hill land in the Malay States ranges from £1 15*s* 0*d* to £4 10*s* 0*d* per acre The cost of maintenance has not exceeded 10 per cent of the first cost in the year following construction and 5 per cent in the succeeding years It must be realized that maintenance must commence the day after construction is completed (Evans[168])

In place of tile pipes subsoil drains may be constructed with sides roof and floor made of flat stones (Fig 7 B) Drains of this type varying in size from 6 inches to 12 inches wide and from 9 inches to 15 inches deep were installed at Meenglas, Bengal in 1917–1919 at an average cost of 11¾ annas per foot run, and after 8 years working with very little cost in maintenance they were found to be in as good condition as ever[1 9]

Where stones are not available larch or other poles may be laid lengthwise in the bottom of the drain one on each side and one on the top forming a conduit (Fig 7 C)

Another method is simply to make deep trenches and fill them with stones but in this case it is necessary to dig them up and clean out the silt at intervals

(*c*) *Vertical drainage* This may prove a useful and economical measure especially in the case of swamps and marshes The bed of the marsh is probably of silt or clay which retains the water, but underneath this there may be a permeable or fissured rock which will give drainage In order to drain the marsh a pit is sunk down to the permeable rock the exposed surface of which is blasted The pit should be filled with rock filling, a vertical line of pipe being carried to the level of the marsh bottom The pipe should be surrounded with stone or gravel Spigot and socket sewer pipes or iron pipes coated can be used or a circular pit built

of small sized stones, and should extend 2 or 3 inches above the surface of the ground[184]

(iii) In dealing with hill streams in ravines, it is necessary that the pipes should be buried *at least* 3 feet deep * The pipes should be covered by a layer of heavy stone, the smaller stones being placed above as before, but in order to prevent silt from reaching the pipes and blocking them, it is necessary for the topmost layer itself (i e , the floor of the ravine) to be of silt In wet climates a layer of grass will grow over this, and will prove efficacious against scouring It is most important that trees

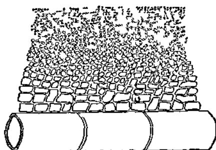


FIG 8

Subsoil tile drain longitudinal section (after Le Prince[184])

growing within a distance of some 40 feet from the pipes shall be rooted out, otherwise their roots will grow down into the pipe junctions and block them

The advantages claimed for subsoil drainage as compared with open drains are that it is self cleaning maintains itself permits of rapid inspection needs very little attention, requires no oiling and permits of no exposure of water accessible to mosquitoes It should be pointed out, however that the laying of pipes should as a rule, only be undertaken by a skilled engineer Its principal

* A Circular [66] issued by the Public Works Department F M S in 19?? laid down that there should be not less than 4 feet of cover over the pipes

How Oil Kills Mosquito Larvæ

It was originally supposed that the lethal effect of oil on larvæ was due solely to the fact that it suffocated them by cutting off their air supply. A great deal of investigation has since been carried out as to the manner in which oil kills larvæ, the various theories put forward being as follows:—

(i) Suffocation of the larvæ by producing a surface film which cuts off their supply of air.
(ii) Blocking of the respiratory tubes by particles of oil.
(iii) Toxic action of oil vapours.
(iv) Toxic action of the oil directly by contact.
(v) Toxic action of the oil indirectly by solubility in the water.
(vi) Reduction of the surface tension making it difficult for the larvæ to remain at the surface and thus causing them to drown.

Freeborn and Atsatt[340] found that the toxicity of oils increases with their volatility and that the volatile constituents contain the principles which produce the primary lethal effect, but that in the case of those oils with negligible volatility (boiling point over 250°C.) the lethal action may be due either to blocking of the respiratory tubes, poisoning by contact or even by suffocation. They did not consider that the reduction of surface tension or toxicity from solubility in water had any effect.

More recent researches have in the main confirmed these observations. Green[345] showed that the rapidity with which larvæ die depends on the volatility and toxicity of the oil, that the larvæ obtain their fatal dose of oil in a very short time (less than 1 second with petrol and within 1 minute with an absolutely non-toxic oil, Nujol) and that *Culex* larvæ take a very much longer time to die than *Anopheles* (6 to 8 times as long).

Hacker[3 0] pointed out that oil frequently kills larvæ without the production of a complete film. He laid stress on the importance of "differential wetting" in the susceptibility of larvæ to the effects of oil. Oil on the surface of the water acts like a

up in dry stone masonry A circular strainer should be put in round the mouth of the sinkage (Home[177]) Probably several of these pits will be necessary if the marsh is a large one A certain amount of grading will be required in the marsh leading to the sink holes (Fig 9)

(See *Bibliography*, Nos 155–195)

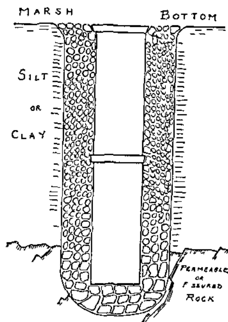


FIG 9

Vertical drainage (after Home[177])

3. Oiling.—The use of oil to diminish the number of mosquitoes was recommended in a note in *The American Advertiser*, Philadelphia, in its issue of August 29th 1793 (McFarland[363]) It was also suggested in a work entitled 'Omniana Otiosores,' said to have been written by R Southey, which was published in London in 1812 The first published account of scientifically conducted experiments with oil as a mosquito larvicide appears to have been that of Howard[353], which appeared in 1892

The addition of small quantities of a vegetable oil also greatly increases the spreading of mineral oils According to Hacker[350] vegetable oils probably spread by virtue of the free fatty acids which they contain Leak[362] recorded that the addition of 1 per cent of castor oil to kerosene increased the spread 25 times. He found that 2 ozs of kerosene covered an area 5 yards in diameter, whilst on the addition of 1 per cent of castor oil an unbroken film 30 yards in diameter was formed

If the oil contains too much active material (OH groups, COOH groups etc) the excess leaves the oil, satisfies the affinity of the water for active groups and therefore prevents the oil from spreading This is a point of practical importance, since the addition of too much cresol, vegetable oil etc , will actually decrease the spreading power instead of increasing it A method of testing whether too much active material has been added to, or is contained in an oil is by shaking up a sample with water , if this water then prevents the spread of oil it has been inactivated by the excess of active material

The spreading of oils is also increased by oxidation Hacker[350] showed that kerosene and crude oil increased in spreading power when exposed to air for 8 days It was found by Johnson[358] that oil soaked sawdust caused a better film when left for 24 hours before use, and also that certain waste oils from garages did not spread well until they were soaked with sawdust Hacker considers that the improvement in spreading power was in this case probably due to oxidation and not to the filtering out of carbon particles by the sawdust, as Johnson suggested Sollmann[375] found that the spreading of kerosene was increased by adding asphalt and Hacker suggests that this may be because the tar causes oxidation of paraffins by catalytic action Hacker also noted that the toxicity of kerosene was increased by oxidation as well as the spreading power

The presence of dust or grease on the water, or of soap or soapy material in the water, prevents oil from spreading, and this has to be taken into account when considering the amount of

dry object, and attracts the spiracles (which are also dry) When contact takes place the oil is able to wet the spiracles and enter the breathing tubes Contact with oil is sufficient to kill larvæ '

Oil also tends to deter the adults from depositing their eggs, whilst it kills the algæ forming with them a dense floating mass which probably has a deleterious effect, and in any case reduces the food supply of the larvæ In its place there appears a closely felted alga attached to the stones or sand forming the bed of the stream or pool, the presence of which forms a useful indication as to whether oiling has been carried out effectually[45]

The spreading power of oils

The popular opinion is that the lighter kerosenes spread better than the crude oils, but some authors state the reverse Hacker[350], in his laboratory experiments, found great difficulty in producing uniform films from the same amount of oil dropped on the same amount of water in the same size Petri dish He explained this phenomenon by the formation in some cases of an 'invisible film' of greasy substances derived from the fingers during the preparation of the dish, inhibiting the spread of oil This may be the explanation of the conflicting statements which have been made regarding the spreading power of various oils

The spreading of oils, however, does not depend on viscosity, and a thin oil does not necessarily show better spreading powers than a thick Ginsburg[349] has shown that the tar acids having hydroxyl (OH) groups (e g, phenols, cresols, xylenols), increase the spreading power of mineral oils, as also do the monohydric alcohols pine oil and turpentine Cresols and xylenols proved more efficient than the other compounds, the addition of one gallon of crude cresol containing 95 per cent cresylic acids to 100 gallons of fuel oil greatly increasing the spreading and penetration of the oil on salt and fresh waters covered with dead organic matter and vegetation In laboratory experiments it has been found that the addition of 1 per cent cresol to fuel oil increases the spreading power by 50 per cent The duration of the oil film is also appreciably increased by this treatment

(a) *Kerosene oil*—This may be applied alone but there are certain objections to its use —

(i) The film is so thin that a very slight disturbance of the water surface by floating debris projecting vegetation ripples caused by the wind or current etc, break the continuity of the film

(ii) It is expensive and likely to be stolen by unscrupulous employees

(iii) It is transparent and therefore likely to be wasted by the persons applying it because it is difficult to see whether the film is satisfactory

(iv) There is risk of fire e g where sparks from a passing railway train may drop into it

The quantity recommended for use by Howard[353] was one ounce to 15 square feet of surface the film produced lasting about 10 days

(b) *Crude oil and other unrefined oils*—The liquid fuel of the petroleum companies is not properly speaking crude oil but a refuse after some of the more volatile oils have been distilled off Its composition varies considerably in different consignments Watson[45] notes that some consignments can be used alone whilst others need the addition of one part of kerosene to 8 parts of liquid fuel before use with a sprayer The dark tarry solution of extractives which is found at the bottom of the oil drums is toxic to larvæ and is very useful for application in springs etc The addition of from 1 to $2\frac{1}{2}$ per cent of a vegetable oil castor coconut or whatever kind may be available locally will increase the spreading power of crude oil or liquid fuel to a great extent castor oil being the most effective

Kligler[108] in Palestine found that the most effective mixture was 1 part of crude oil to 4 parts of kerosene with from 0 1 to 0 2 per cent of castor oil added.

Williamson and Rajamoney[385] suggested the use of a mixture containing equal parts of crude oil solar oil and rubber oil Rubber oil does not increase the spreading power of the other two but

vegetable oil, etc, to be added The presence of grease or soap explains why an oil which may give excellent results on natural waters will often lie in patches when applied to water containing drainage from dwellings

Williamson and Rajamoney[385] lay stress on the fact that *very* great spreading power is not always an advantage being only permissible in limited areas of pure water, and in the presence of weed or other factors which retard film formation A very thin film of oil is an ineffectual destroyer of mosquito larvæ

The choice of oil

There are many grades of oil on the market which may be *used for mosquito destruction, ranging from the very light oils* such as kerosene to the heavier forms known as crude oils The *choice of an oil will depend very largely on local conditions, thus,* with high temperatures a thick oil is required, whilst in the presence *of vegetation an oil with great spreading power is necessary* Again in the case of still water a heavy non toxic oil applied *in sufficient quantity to form a complete film will after some* hours kill all the larvæ, whilst in the case of moving water a *thin layer of rapidly spreading oil with a high toxicity is* indicated

As already stated the poisonous action of mineral oils is related to several factors—viscosity, volatility, and the presence of aromatic hydrocarbons or of certain natural poisons A thin oil will enter the breathing tubes of the larvæ quicker than a thick, whilst as we have seen, a high volatility and a high percentage of aromatic hydrocarbons increase the lethal effect Unrefined oils, such as fuel oil or diesel oil, contain small quantities of substances (organic acids nitrogen and sulphur compounds) which appear to exert a poisonous effect These are partly removed by refining processes, and a highly refined lubricating or paraffin oil will therefore prove less poisonous than a *black* fuel oil of the same thickness

Barnes[328] has found a mixture of 9 parts of crude oil with 1 of pine oil effective The latter, which contains various alcohols and ketones, has a powerful soporific or paralysing effect on the larvæ, and also increases the spreading power of the crude oil.

(c) *Liquid paraffin* (liquid vaseline) has been used by Swellengrebel and his co workers[393] in Holland It is an almost colourless oil, costing about £1 per cwt It is claimed for this oil that it does not need the destruction of vegetation, that its effects are not vitiated by wind or rain, that it does not evaporate and therefore has a lasting effect and that it does not prevent mosquitoes from depositing their eggs It is also non toxic to fish Although it costs five times as much as paris green, its use in the smaller canals in Holland (where manual labour is very expensive) entails less expense, because it is so easily and quickly applied Five or six c c of the preparation are used per square metre of water surface

(d) '*Leron*' a mixture of various mineral oils, has been used with success in Italy and elsewhere It is claimed for this preparation that it is harmless to fish and cattle and that it gives satisfactory results in the proportion of 10 c c to the square metre of water surface, even in the presence of dense vegetation, it being sufficient to move the reeds, etc a little to ensure uniform spread (Gratch[344])

(e) *Petrol*, in the proportion of 24 ozs for every 80 square feet of surface, has been recommended for use in wells, tanks etc It is claimed that larvæ are immediately destroyed by this method, and that in 2 hours there is no smell and in 3 hours no taste of petrol in the water It is suggested that the petrol should be applied in the evening[371]

Methods of applying oil

(i) *Spraying* by means of a spray can or knapsack sprayer. By this means the oil can be distributed to a distance of 20 to 30 feet from the operator The sprayer when filled must not be too heavy, a pattern with about $2\frac{1}{2}$ gallons capacity being suitable

greatly increases their toxicity Solar oil, a heavy fuel oil derived from aromatic crude oils, probably imparts continuity to the films whilst the inclusion of crude oil is justified on account of its low cost, and the fact that it evaporates less quickly than either of the others thereby prolonging their continuance on the water surface

Anti malarial oil (A M M) is a mixture containing diesel oil solar oil and kerosene put up by the Asiatic Petroleum Company Diesel oil is unrefined and non volatile at ordinary temperatures and is added to give a lasting effect Poisonous substances also occur naturally in this oil[325]

Pesterine (M D B) prepared by the Burmah Shell Oil Company, is another mixture of oils recommended for anti mosquito work Its present price is Rs 32 13 per 42 gallon drum It is claimed that this is slightly superior to A M M

Feegrade[337] experimenting with various crude oil products of the Burma Oil Company, Rangoon found 'Bauxite extract' to be the most effective

Walch and Bonne Wepster[380] recommend the use of 'sludge a waste product from the Batavian Petroleum Company, used in the proportion of 7½ to 10 c c per square metre of water surface

Waste motor oil ('crank case oil') has been tried extensively in America Peterson and Ginsburg[367] note that this usually needs straining and does not spread on water but may be made to do so by adding a tar acid containing 25 per cent cresylic acid or by adjusting the specific gravity to 32 or 34 Be by adding light petroleum distillates They state that the lasting quality of the oil mixture is 2 to 4 weeks twice as long as that of fuel oil and that the cost is only half that of the latter Walch and Bonne Wepster[380] also used waste motor oil and found it effective when mixed with 10 per cent kerosene and 1 to 2 per cent coconut or castor oil 10 to 20 c c of the mixture being applied per square metre of surface They also obtained good results with a mixture of 3 parts waste oil and 1 part solar oil Waste crank case oil destroys vegetation

PLATE I



A O Sp aye w h Doub e Ac on Pump (Ladywood No 28



B H gh P essu e O l Sp aye Fou Oak Kent N

for use by an Indian coolie There are two principal types of sprayer on the market one fitted with a double acting pump which has to be worked continuously by hand (e g the Ladywood Sprayer No 28) and the high pressure type (e g the 'Four Oaks' High Pressure Sprayer and the Mysto Gem Sprayer No 8) in which the pressure is pumped up to a standard figure marked on a gauge before use (Plate I) The latter type though more expensive is less fatiguing for the operator and leaves one hand free a great advantage in rough country In America the Myers 3 gallon compressed air sprayer fitted with a 2½ feet extension and a graduating vermorel nozzle has been found satisfactory

The sprayers should preferably be fitted with leather or fibre valves and flexible metallic hose as petroleum oils cause ordinary rubber to perish In any case since leaks at the base of the hose are common it is advisable to obtain a spare hose as well as a spare set of washers when ordering the machine The choice of nozzle is important Senior White[68] recommends a pattern which will deliver a cone spray about 18 inches in diameter 4 feet in front of the nozzle He finds the Marvellous' nozzle and the I T A attachment with Marvellous' nozzles of the 'Four Oaks' Company the most suitable A defect of many nozzles is that they deliver too much oil per minute so that the operator must either proceed at a run or waste oil

The oil should be filtered into the sprayer through a sieve (which is usually supplied with the machine) and after each day's use the apparatus should be washed out by pouring a pint or so of kerosene into the container and blowing it out through the nozzle by pressure All spraying requires supervision by some intelligent individual whose duty it is to see that the jets do not get blocked and to re pack joints and valves[69]

(ii) A garden *watering-pot* may be used for sprinkling oil on small pools drains etc

(iii) *Used cotton waste* may be employed economically where there is much machinery This may be made into swabs and

if they are not already sufficiently oily, these can be soaked in crude oil and wrung out before use Senior White[28] states that they are ideal for use in small rock springs and that by their use running water is more economically oiled than by a machine They may be weighted down with a brick or stone or pegged into the ground with small sticks Bits of old sacking may also be used in this way After about a week the swabs may be re soaked and used again

(*iv*) A long stick with a bundle of old sacking tied on the end may be used to distribute oil over small pools

(*v*) *Balls or guddas* (pillows) may be made of tow or sacking weighted with stones and thrown into pools etc after being soaked in heavy oil The oil oozes out gradually and comes to the surface A better plan is to have them attached to a float (made by sealing up an empty tin) so that they do not sink to the bottom (Fig 10) This prevents the collection of silt round

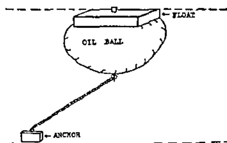


Fig 10
Oil ball and float

them which eventually makes them ineffective They may be placed in drains or tethered along the edges of streams irrigation channels etc They should be opened out and dried at intervals *of 7 to 10 days and re-soaked in oil* It is also well to shake them every 2 days or so without removing them from the water A 'gudda' shaped like an ordinary pillow, 28 inches long and

The amount of oil allowed to drip suggested by Le Prince[369] is 10 to 20 drips per minute for a water surface one foot wide

The disadvantages of oil drip-cans are that they do not give good service without proper attention and may get clogged or be washed away by floods or be stolen

(x) In Panama a *barrel pump* mounted on a rowing boat is used Hot oil is employed because it is found that this flows better through the pipes and nozzles[339]

Amount of oil to be applied

It will be evident from what has been said above that the amount of oil necessary to control mosquito breeding will vary very greatly according to the local conditions obtaining i e climatic conditions presence or absence of vegetation kind of oil or mixture of oils employed etc However as the question is so frequently asked in connection with the probable cost of anti larval measures it may be laid down that half an ounce of oil per square yard of water surface or 15 gallons per acre is usually an ample estimate It is claimed for some of the proprietary preparations that very much less than this is needed The exact amount of oil required in any particular case can only be ascertained by actual trial in the field

Frequency of oiling

It is usually said that oiling should be repeated every 10 days but in practice it will be found more effective to oil at intervals of 7 days This is not because such a practice is essential to control breeding but because unless it is definitely laid down in the programme that such and such breeding places are to be oiled on a specific day of each week it is inevitable that certain places will be missed Like everything else in connection with malaria prevention the success of oiling depends on the thoroughness with which it is carried out Oiling should not be attempted in drains or streams during heavy rain Should a heavy downpour occur within an hour after oiling the process may have to be repeated[*9]

16 inches broad made of sacking will soak up about 2 gallons of oil at first and about 1 gallon when re soaked It will last about 3 months Oil balls may also be dragged along drains like mops thus clearing the drain and at the same time oiling it

Lumps of tow or sacking soaked in oil and weighted with a brick are useful in treating water under culverts

(*vi*) Oil may be mixed with *sawdust* and thrown after the manner of sowing grain -The mixture must not be wet to the touch and the particles must separate cleanly when thrown on to the water The best results are obtained when the mixture is allowed to stand for 24 hours before use (*see* p 47) This method has been advocated for use among vegetation The proportions to be used are roughly 30 gallons of oil with 10 bushels of sawdust per acre[358]

(*vii*) A conical can divided into a lower chamber to contain sand and an upper chamber for oil has been devised by Wetmore[383] A tube soldered to the outside opens into the oil chamber at the bottom The apex of the oil chamber has a wick to permit the oil to escape The can is thrown into the water and sinks air escaping from the apex followed by oil Water is drawn through the tube into the lowest portion of the oil chamber replacing the oil This device is said to work well in water covered with vegetation

(*viii*) Standing rain pools on grass may be dealt with by means of an ordinary sweeper's broom dipped into oil and brushed round the edges

(*ix*) *Drip cans* may be used for the automatic oiling of streams and drains They may be used as follows

(*a*) A nail may be knocked through the bottom of the receptacle and a piece of wool wrapped round the head of the nail By pulling on the latter the flow may be regulated

(*b*) A tap may be fitted to the receptacle

(*c*) A thick lamp wick may be stuffed into a hole near the bottom of the receptacle

(*vi*) It renders water unfit for drinking purposes

(*vii*) It is likely to deter mosquitoes from depositing their eggs thus driving them to other unoiled collections of water

(*viii*) It is likely to be stolen by unscrupulous employees

Advantages of oiling

(*i*) Oil kills the ova and pupæ of mosquitoes as well as the larvæ

(*ii*) It kills culicine as well as anopheline larvæ

(*iii*) It is easily obtainable everywhere

(*iv*) It is easy to see whether it has been properly applied

(*v*) No elaborate apparatus is required for its application

(*vi*) Its use though requiring supervision does not involve the amount of supervision as does for instance that of paris green

(See *Bibliography* Nos 374–380)

4 Chemical larvicides (a) *Paris green* (copper aceto-arsenite) —Following the publication by Roubaud[389] of the results of his researches as to the value of paraformaldehyde powder as a larvicide Barber and Hayne[395] in 1921 carried out experiments with various compounds of arsenic of which paris green proved the most efficient Since then it has been used widely in many countries and it appears to come nearer to fulfilling all the requirements of an anopheles larvicide than any other preparation at present available

Paris green (Schweinfurt green Imperial green Emerald green Mitis green) is a micro-crystalline powder of emerald green colour practically insoluble in water but soluble in ammonia and in concentrated acids Under United States law the name paris green is restricted to powders containing a minimum of 50 per cent arsenious oxide but in Europe the name is sometimes applied to substances containing green aniline dyes which are valueless for larvicidal purposes

Tests of thorough oiling

Apart from the absence of living larvæ, two other tests of the efficiency of oiling may be mentioned —

(i) The marginal vegetation along a properly sprayed drain should be burned brown for a foot on each side and after a few applications bare earth margins should become exposed

(ii) In regularly oiled drains *Spirogyra* will disappear and be replaced by a bottom growth of a matted Cyanophylaceous alga, which as pointed out by Watson[4] is correlated with the absence of mosquito larvæ.

Where oiling is applicable

Oil may be applied in the case of pools, drains and *streams* and to the edges of deep ponds lakes and rivers, and wherever it is necessary to destroy culicine as well as anopheline larvæ provided that the water is not to be used for drinking or domestic purposes It is especially applicable to temporary collections of water which are too numerous to drain or to control breeding places while steps are being taken to deal with them by permanent measures

Disadvantages of oiling

(i) Oil will not easily penetrate a barrier of grass, and to make it thoroughly effective all vegetation and floating débris should be removed

(ii) Wind will break up an oil film and will carry the oil to one side of a sheet of water

(iii) During rainy periods the value of oiling is decreased Showers of rain wash away the oil

(iv) Oil is heavy for transportation

(v) It may kill fish, and renders them unfit for human consumption

(ii) It renders water unfit for drinking purposes

(iii) It is likely to deter mosquitoes from depositing their eggs, thus driving them to other unoiled collections of water

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Method of action of paris green

The particles are eaten by the anopheline larvæ, which feed on the surface of the water, and the chemical acts as a direct poison It is therefore important that the particles of paris green should remain floating on the surface for as long a period as possible This is largely determined by the surface tension of the water The more vegetation that is present in the water the greater is the surface tension, the longer do the particles float, and hence the greater is the efficiency of the paris green as an anopheles larvicide Experiments are being carried out by various firms with the object of producing a form of the chemical which will remain on the surface for the longest possible time

Paris green has no effect on the pupæ of mosquitoes, because these do not feed, nor, when applied in the usual way does it affect the larvæ of culicines because these are not surface feeders The very young (first day) larvæ of anophelines are also usually unaffected, presumably because the particles of paris green are too large for them to eat It is possible that this latter difficulty may be overcome by the production of an extremely fine form of the chemical

Requirements of a good paris green

(i) It should be of a deep green colour

(ii) It should contain over 50 per cent arsenious oxide, a good quality averages 55 per cent

(iii) Its solubility in water should not exceed 3 per cent

(iv) It should be capable of being passed through bolting cloth of at least 200 preferably 300 mesh

(v) Each batch should pass a practical field test before acceptance for it has been found by experience that samples apparently identical vary greatly in toxicity to larvæ

Choice of diluent

For use paris green is mixed in varying proportions with a dry powder of some description which acts as a vehicle for its

distribution * A very large number of substances have been used for this purpose amongst which the following may be mentioned —

Road dust	Sulphur	Cement dust
Slaked lime	Spoiled flour	† Trass
Powdered soapstone or soft stone	Red earth (Java)	Sawdust
Ashes	French chalk	Fine sand
Cork dust	Coir dust	China clay

The choice of diluent will depend on the conditions under which the larvicide is to be used Other things being equal the cheapest suitable diluent locally available will naturally be selected

(i) For dusting an extensive area such as a swamp or large sheet of water a light vehicle which will carry the paris green with it for a long distance in the wind is required Soapstone or ' soft stone (which consists chiefly of silicates of lime and magnesium) and slaked lime have been found suitable for this purpose in India The former may be obtained in the form of a powder (for sources and prices *see* Appendix) Slaked lime is prepared from quick lime which can usually be obtained locally The lime should be of good quality and the slaking done with care a small quantity of water being added at a time The process of slaking should never be carried to completion During the process of screening (*see* below) which should be done shortly before use the unslaked portions will be removed and should be put back with the unslaked lime for future use In moist climates simple exposure to the air is sufficient

Road dust varies in composition in every locality and very frequently contains a considerable quantity of sand which makes it unsuitable for dusting large areas

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* Kerosene oil or a mixture of kerosene and waste motor oil has also been used as a vehicle for distributing paris green in order to obviate the necessity for storing dust during rainy seasons

† Trass is a volcanic substance largely composed of pumiceous dust and is worked for mortar

(ii) In the case of small streams, ditches, irrigation channels etc, a heavier diluent is required, as, if there is any considerable wind a light vehicle such as powdered soapstone or slaked lime is likely to be carried beyond the breeding place This is a point of very great practical importance indeed, with a very light diluent if the wind is at all high, the attempt to dust such breeding places may be absolutely ineffective The local road dust will frequently be found suitable for this purpose, or fine sand alone may be used

Swellengrebel and his co workers[393] in Holland first used ashes as a diluent, with 1 per cent of paris green They found that some of the larvæ survived after the first day, and concluded that this was because some of them swallowed large quantities of ashes besides, or even instead of, paris green They therefore sought for a heavier dust, which would sink, leaving the paris green floating on the surface of the water and finally selected trass as being more suitable

Williams[453] and other American workers on the other hand, who wish to dust very extensive areas by means of electric blowers and aeroplanes and who use paris green in dilutions of from 5 to 33 per cent prefer a diluent which will float for the longest possible time such as soapstone or slaked lime

Recent experiments by Dolloff[412] have shown that mixtures of hydrated lime with the stearates of calcium and aluminium as diluents for paris green prolong the period from the time of dusting to the re appearance of anopheline larvæ from an average of 3 days to an average of 5 to 6 days, in spite of intervening showers of rain

Screening

Whichever diluent is employed, it is usually necessary to pass it first through a screen or sieve, in order to get rid of the larger particles For this purpose it is customary to use an apparatus consisting of a double cylinder of wire gauze, the inner one through which the dust first passes) being of coarse mesh (about 2 to the linear inch) the outer of a finer mesh (about 30 to the

linear inch) The cylinder is mounted within a wooden box on a stand and is operated by turning a handle* (Fig 11)

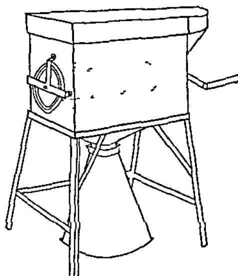


FIG 11
Screener for dust to be used as diluent for paris green (after Missiroli)

A simpler type consists of a rectangular wooden tray about 2 feet long by 1½ feet broad with a fine wire gauze bottom on the

* The following dimensions for this screener are given by Missiroli [illegible] —

Box	Length	58 cm
	breadth	31
	height	4[illegible]
Hopper	radius	21
Sieve	length	57
	slope	4
	diameter of internal cylinder	18 cm
	mesh of gauze of	7 to 1 cm
	diameter of external cylinder	24 cm
	mesh of gauze of	15 to 1 cm
Tressle	length	60 cm
	breadth	33
	height	[illegible]0
Bucket	diameter of mouth	15 cm
	base	37 ,,
	height	47 cm

top of which fits a second tray with a bottom of coarse mesh wire The screener is suspended from the roof by cords attached to its four corners and is agitated by hand, after the manner of sifting grain The larger particles are removed by the upper tray This apparatus which may be made locally at very small cost (about Rs 5 in India) has been found suitable for screening road dust It has the great advantage that there are no complicated parts to get out of order[404]

Mixing

This must be thorough, so that the resulting mixture is uniform A suitable apparatus may be constructed from a rectangular box of galvanized iron suspended on two pillars from diagonally opposite corners and turned by a handle (Fig 12) A

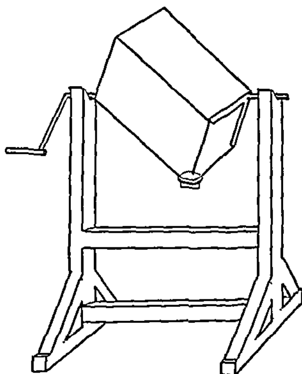


FIG 12
Mixer for use with paris green (after Missirol [411])

PLATE II



A Haversack for the application of paris green by hand



B Rotary Blower (Peerless Dust Gun) for Paris green dusting

convenient size is 33×48 cm (about 13×19 inches) Or, an oil drum or small barrel with an iron rod running diagonally through it may be used About 200 turns are necessary for satisfactory mixing

Methods of application

(i) *By hand* —The mixture may be thrown by hand after the manner of sowing grain from a bag resting on the hip and suspended from the opposite shoulder This method has the advantage of dispensing with mechanical blowers, which so frequently get out of order in the hands of the average coolie, and is probably the best way of applying paris green to irrigation channels, drains, etc , in the tropics (Plate II, A)

(ii) *Hand bellows* can be made locally in any bazaar for about Rs 10, and have been recommended for treating small streams irrigation channels ditches, etc Their use is, however, fatiguing to the operator, and they are soon broken by the average coolie, so that in the tropics distribution by hand is usually preferable

(iii) *Knapsack sprayers* are used extensively in Italy, where the local peasant is accustomed to employ the same apparatus for spraying his vines with sulphur etc For use with road dust in India they have been generally found unsuitable owing to the frequency with which jamming occurs They may be used for lighter dusts, such as slaked lime though even then they are apt to get clogged at times when this happens it can often be remedied by inverting the machine and shaking it vigorously

(iv) *Rotary blowers* —There are many of these on the market, and though more expensive than the knapsack sprayers they are much more effective in dealing with large areas The container for the dust and that for the mechanism should be completely separated It is also an advantage for the dust container to be placed behind the operator (as in the case of the 'Peerless Dust Gun') and the gear box and fan in front, the blower is then better balanced, and is less fatiguing to operate than if the whole apparatus is carried in front of the body (Plate II, B) The gears and fanshaft should preferably run on ball bearings.

(v) *Electric blowers* —A dusting unit consisting of a power generator an electric blower and a small dust hopper has been used with success in America in dusting large sheets of water from a boat With this machine using a 15 per cent mixture of paris green with slaked lime a lethal path 525 feet wide has been obtained with a moderate breeze (7 or 8 miles per hour)

(vi) *Dusting from aeroplanes* —Insecticidal dusts were first applied to crops from aircraft in the U S A in 1921 and King and Bradley[403] employed this method for dusting with paris green in experiments conducted in 1922 24 It has been found an effective means of controlling anopheline breeding in large swamps both in the United States and in Italy A ' venturi tube some 2½ feet long by 8 inches square at the mouth 74 inches in the centre and 12 inches at the outlet in the rear is fixed beneath the fuselage of the plane The dust is fed by gravity from a V shaped hopper 30 inches high into the constriction of the venturi tube the lower aperture of the hopper being controlled by a sliding door which can be operated by the pilot When the aeroplane is travelling at high speed (about 65 miles per hour) a high velocity of air current is created at the narrowest part of the venturi tube and a partial vacuum at its outlet The dust is well broken up as it enters the partial vacuum and is blown out of the tube in an even cloud By this method a lethal path some 200 yards wide is obtained Cook and Williams[409] state that a properly equipped plane flying 4 hours a day for 5 days a week could deal effectively with an area of 20 square miles

Methods of determining toxicity of paris green suitability of diluent etc

In carrying out preliminary tests to estimate the toxicity of a batch of paris green the distribution and concentration of the mixture and the suitability of the diluent the following methods may be used —

(i) Various points in the area to be dusted are selected and a specified number of dips are made in each breeding place with a ladle or dish the average number of larvæ obtained per dip being

counted The places where the dipping was done are marked b stakes About 3 hours after dusting the process of dipping repeated and the results compared

It should be borne in mind that the length of time which larvæ are killed depends not only on the degree of concentration of the paris green but also on the temperature of the water In warm weather the larvæ will feed much more actively and will thus be killed more quickly whilst when the temperature is very low they may not be feeding at all in which case any brand of paris green will be ineffective It is therefore important when comparing the efficiency of different samples of the chemical to carry out the tests under similar climatic conditions

(ii) Dishes containing known numbers of living larvæ are placed at various points over the area to be dusted and the numbers killed or remaining alive after dusting noted This method though useful does not give as conclusive evidence of the mortality rate as does (i)

(iii) Glass microscopic slides with a one inch square ruled on each are placed at various points It is convenient to place these across the corners of the dishes used in (ii) After dusting the slides are collected and the number of paris green particles per square inch on each is counted under the two-thirds objective of a microscope For effective dusting there should be at least 12 particles per square inch *on each slide* This is a very useful method for estimating the distribution and concentration of the paris green

Strength of paris green to be used

For dusting narrow streams, drains small pools etc a one per cent dilution of paris green is sufficient For use over larger areas from 2½ to 5 per cent or even more will be found more effective For the electric blower a dilution of 15 per cent is recommended whilst for distribution from aircraft Cook and

Williams[109] have found that 33 per cent is the most suitable for all conditions of wind *

Quantity of paris green to be used

Hackett[417] uses 0 1 c c (0 125 gm , 1 9 grains) to the square metre of surface Thus a litre (1,250 gm) should control breeding over 10 000 square metres of surface, or along 10 kilometres of water edge This works out at approximately 1 lb of paris green per acre, which is the amount usually recommended †

If carefully applied in high dilution with a hand blower it is possible to control breeding with less than half this amount but in practice it is found that such extreme care in application is not economical from a labour point of view

The presence of scums or dense vegetation on the water surface necessitates the use of somewhat larger quantities of paris green per unit area

Frequency of dusting

As in the case of oiling this will depend very largely on local conditions, such as intensity of breeding and variations in climate As a general rule where breeding is profuse paris green should be applied once a week Sometimes, where the period of develop ment of the larvæ is shortened owing to specially favourable climatic conditions, it will be found necessary to reduce this interval to 5 or 6 days for a while Again, as the weather becomes colder and the period of larval development becomes lengthened it may only be necessary to dust at intervals of 10 days or so Even in this case, however, a seven day interval is to be

* Some workers measure the dilution by weight, others by volume As some diluents are much lighter than others and may be less than half as heavy as the paris green the two methods of calculating the dilution may give widely different results It is considered advisable always to make the dilution by volume in any case, in recording results, it should invariably be stated which method has been used in calculating the dilution

† Barber and Hayne[395] recommended 10 c c (12 grams, 0 43 oz, 0·6 cubic inch, or 2 level teaspoonfuls) to 90 square metres (1,000 square feet)

recommended, as if it is laid down that each breeding place is to be dusted regularly on a certain fixed day each week there is much less likelihood that any particular breeding place will be overlooked

Summary of recommendations as to the methods of applying paris green in the tropics

From the results of experiments carried out by the Malaria Survey of India up to the present date the following procedure is recommended —

(i) For dusting large areas a 2 to 5 per cent dilution of paris green by volume in slaked lime or powdered soap-stone (or soft stone') applied by means of a rotary blower ½ to 1 lb of paris green to the acre

(ii) For treating narrow irrigation channels ditches, etc a 1 per cent dilution of paris green in road dust, or fine sand applied by hand from a haversack

Cost of application

This naturally varies considerably according to the local conditions As a rough guide it may be mentioned that the cost of applying a 5 per cent paris green mixture with slaked lime at Karnal Punjab by means of a rotary blower, using ½ lb of paris green per acre works out at about As 12 per acre This includes the labour for slaking the lime but not the wages of the coolie distributing the mixture No allowance is made here for the cost of the blower

Effects of paris green on other forms of life, etc

Workers with paris green are practically unanimous in stating that in the quantities in which it is used as a larvicide this chemical is harmless to man and domestic animals who may drink the water so treated or to fish or any other forms of aquatic life except mosquito larvae

Hackett[417] quotes Davis[398] as mentioning the poisoning of some ducks and chickens with paris green on one occasion in Brazil. In a private communication Dr Davis informs me that on this occasion some dead chickens and ducks were found on the day following the application of paris green to some pools, but that subsequent inquiries elicited the fact that chickens were also dying in other parts of the town, in which paris green had not been applied, presumably from some epidemic such as fowl cholera. It is unfortunate that this report should have found its way into the literature. In point of fact, birds are particularly resistant to the effects of arsenic.

There is on record an observation by Herrmann, Kolossow and Lipin[4 0] that one out of three rabbits to which drinking water which had been sprayed with paris green was given over a prolonged period developed a paralysis of the hind foot which suggested the possibility that paris green dusting was not so harmless as had been supposed. The investigations of other workers however have tended to show that under natural conditions there is no accumulation of arsenic in solution in water to which paris green has been applied over long periods. Hackett[417] using *Penicillium brevicaule*, a mould which gives off a characteristic garlic odour in the presence of a medium containing one part in 100 000 of arsenic, found that samples taken daily from shallow pools of standing water gave strongly positive tests 24 hours after treatment with paris green, but were always negative after 48 hours. He concluded that arsenic does not accumulate in such collections of water, but is rapidly eliminated, 'perhaps through volatilization by the microflora of the water.'

The Schuurmans[446] using a 2 per cent dilution of paris green on fish ponds made various analyses of the water treated, and of fish caught in the water. They found a minute percentage of arsenic in each case, but quantities as large were found at times in the case of the fish and water in untreated fish ponds. They calculated that one would have to drink 27 gallons of the water, or consume 50 pounds of fish in order to obtain a dose of 5 mg. of arsenic.

Paris green has also no ill effect on rice or other crops Nicholls[434] grew rice and certain other plants in tubs in which 2 gm of 2 per cent paris green in coir dust was sprayed over each square yard of water surface without any deleterious effect

As regards the effects on those working with paris green occasional complaints of headache and diarrhœa have been received in the case of men distributing it by hand There have also been cases of dermatitis when mixing has been done by hand Otherwise there appears to be no danger of ill effects and the only precaution necessary is to advise workers to take ordinary care to keep to windward of the dust cloud to change their outer clothing after the day s work and to wash their hands before eating

In this connection there is an advantage in using hydrated lime as a diluent This is somewhat irritating to the throat and nose and workers with it will of their own volition keep to the windward of the cloud as much as possible without any instructions being given to that effect

The question of the effect of paris green on boilers has been raised in connection with the treatment of mill ponds It is difficult to imagine that such minute quantities of the chemical as are used in anti larval work could have any deleterious results In America it has been satisfactorily shown that no ill effects need be feared and the owners of one mill in that country offered to put half a pound of undiluted paris green into one of their boilers as a demonstration of its harmlessness[435]

Advantages of paris green

(i) Its low cost

(ii) Its high toxicity for anopheline larvæ

(iii) Its portability

(iv) Its ease of distribution by wind

(v) There is no need to remove vegetation however dense

(*ii*) There is no ill effect on domestic animals fish or other natural enemies of larvæ or on crops such as rice

(*iii*) The water treated is not rendered unfit for domestic purposes

(*viii*) Being useless for other purposes it is not likely to be stolen

(*ix*) It is quickly applied

(*x*) It does not prevent mosquitoes from depositing their eggs the water treated thus acting as a trap

(*xi*) It is equally effective in fresh or brackish waters

Disadvantages of paris green

(*i*) It has no effect on the eggs or pupæ of mosquitoes and sometimes does not kill the very young larvæ of anophelines

(*ii*) It has no effect on culicine larvæ when applied in the usual way This is a great disadvantage of paris green for although as far as the control of malaria is concerned it is only necessary to destroy anophelines yet the great majority of the general public believe that all mosquitoes carry malaria and if the culicines remain as numerous as ever the campaign is likely to become discredited Moreover there are many places where the ' mosquito nuisance (usually mainly due to the bites of culicines) is so great that it is desirable to destroy these also if only for the personal comfort of the inhabitants, whilst in dealing with diseases transmitted by culicines the use of paris green is of course valueless

In this connection it may be mentioned that Griffitts[414] has reported some success against culicine larvæ by mixing paris green with moist sand so that it is carried to the bottom of the water at once

(*iii*) It is impossible for inspectors to see whether it has been applied properly or not (except of course by dipping for larvæ) Gater[264] has made experiments with various commercial dyes incorporated in the paris green mixture with the object of giving

visible traces of dusting but the results on the whole have been disappointing

(iv) It requires special apparatus for distribution and for screening the diluent and for mixing

(v) Its use requires constant supervision

(vi) It is stated by some authors that it is ineffective in showery weather Nicholls[431], who used a 1 per cent mixture with coir dust stated that it was found almost impossible to destroy larvae during rain On the other hand Swellengrebel and his co-workers[373] using 1 per cent paris green with ash, obtained counts of 32 granules per field within the first 24 hours 'a shower of rain or even three of them making no difference' Dolloff[412], using hydrated lime mixed with stearates as a diluent, also found paris green effective in spite of showers It is difficult to reconcile these statements, and further investigation on the subject is necessary * *A similar difference of opinion exists in* relation to the effect of the presence of dew on the vegetation, some authors stating that dusting is less effective until the sun has dried it up whilst others (e g Williams) state that this makes no difference to the lethal effect It is possible that the choice of diluent may have some influence in both these cases

(See *Bibliography* Nos 395–455)

(b) *Paraformaldehyde* (*trioxymethylene*) This substance was recommended by Roubaud[381] as a larvicide in 1920 The dry powder used alone or mixed with some vehicle such as flour or powdered chalk was spread in the form of a dust cloud on the surface of the water where it was ingested by the larva More recently the same author has described a larvicide having the trade name of stoxal the active principle of which is paraformaldehyde[3 11]

N B —For prices and sources of paris green and the various apparatus used in its application see Appendix

* Barber[—] notes that the action of paris green is most effective immediately after a shower of rain when scums which tend to interfere with the surface spread of the dust particles, are beaten down

During the last few years several workers have tested this substance among whom may be mentioned Barber and Komp[386] Mertens[388] Ginsburg[?68] the Schuurmans[39?] Swellengrebel and de Rook[377] All these have reported unfavourably on stoxal as compared with paris green * and its chief interest lies in the fact that the work of Roubaud with paraformaldehyde and other powders directly inspired the investigations that led to the discovery of the properties of paris green as a larvicide

(See *Bibliography* Nos 386–394)

(*c*) *Cresol* —In reading the accounts of experiments by various workers with this substance as a larvicide one is at once struck by the discordant views expressed as to the strength in which it must be used The reasons for this are that different samples vary in composition that dilutions of saponified cresol deteriorate in toxicity on standing and that the composition of the diluting water also has an effect Harold[106] noted that an acceleration of the larvicidal action occurs with higher temperatures and that the presence of organic silt leads to a reduction of larvicidal power He also showed that the resistance of larvæ to cresol could be enhanced by placing them in non lethal dilutions overnight and transferring them to lethal ones next day a point to be taken into consideration when collections of water are intermittently treated Stewart[116] notes that the germicidal coefficient of a coal tar disinfectant is no sure guide to its larvicidal power and that the hydrocarbon oils probably play a much larger part than might be thought in comparison with the phenoloids

Mayne and Jackson[115] stated that a final dilution of 1 part *of cresol in 1 000 000 was effective for culex* larvæ and 1 in 100 000 for *anopheles* but other observers have found that much larger amounts are necessary † Delmege[105] stated that a dilution of 1 in 100 000 was effective in standing water and 1 in 1 000 in

* It should be mentioned however that Banvallet[3] has reported good results with stoxal

† Hehir[20] states that 1 in 10 000 000 is sufficient but this is evidently due to a misinterpretation of the article by Mayne and Jackson

slow flowing streams, whilst spraying with a dilution of 1 in 500 delayed the growth of vegetation Strickland and Roy[116] found that a dilution of 1 in 50 000 was the greatest to be of any practical utility, Senior White[28] recommends 1 in 40 000 and Marshall[114] 1 in 28 000 whilst Kligler[108] found a dilution of 1 in 10 000 to be necessary Harold found that of two different samples of cresol one killed *Anopheles bifurcatus* larvæ in a dilution of 1 in 10 000 whilst the other had no effect in this dilution

Kligler[109] found this larvicide very useful in Palestine in the case of gravelly marshes along the sides of lakes and river banks where the larvæ are hidden under the pebbles A dilution of 1 part cresol in 100 parts of water sprayed at the upper end of the marsh so that the cresol filters slowly through with the stream either kills the larvæ or drives them out into the stream where they are destroyed

Marshall[114] reckoning that cresol cost about 4 times as much as kerosene oil and that the dilution necessary for the former was 1 in 28 000 calculated that cresol was the more economical method for water with a depth of less than 5 inches For deeper waters the cost of cresol is prohibitive

In the case of mosquito breeding in the water used for keeping cement concrete wet whilst it is setting cresol is a most useful larvicide as it has no ill effect on the concrete In Bombay A *stephensi* breeds freely in such water and the use of cresol has been recommended to deal with this[248] In practice it is found convenient to add just sufficient cresol to make the water milky This is a much stronger dilution than is necessary to kill the larvæ but it makes it easy for the inspecting staff to see at a glance whether the larvicide has been applied

A disadvantage of the use of cresol in natural water is that it kills fish Senior White[28] notes that fish killed by cresol are violently poisonous when eaten by man

(See *Bibliography* Nos 101-116)

(d) *Commercial Cyllin* was used with effect by James[73] in Ceylon One teaspoonful in a gallon of water kills larvæ and pupæ but in practice it was found best to use sufficient to make the water milky after it had been well stirred with a stick

(e) *Sanitas Okol* a proprietary emulsion which appears to contain a large proportion of phenols and allied compounds was favourably reported on by Ross and Edie[101] who found that it was a powerful larvicide effective in dilutions up to 1 in 10 000 at which strength it was non poisonous Mayne and Jackson[115] however found it inferior to cresol

(f) *Panama Canal Larvicide*[257] —This is made as follows — 150 gallons of carbolic acid are heated in a steel tank to 212°F Then 200 lbs of powdered resin are poured in and stirred until completely dissolved 30 lbs of caustic soda dissolved in 6 gallons of water are then added and the temperature kept at 212°F for about 5 minutes A sample is withdrawn and poured into water if complete and rapid emulsion occurs the larvicide is now ready It is claimed for this preparation that —

(i) It is highly toxic to anopheline larvæ a 1 in 1 000 emulsion killing them in 3 to 10 minutes
(ii) It is concentrated and therefore only a small quantity need be carried
(iii) Its toxicity is uniform
(iv) Its composition is simple
(v) Its toxicity to higher animals is low
(vi) Its cost is low
(vii) There is no danger from fire
(viii) It is highly toxic to protozoa and algæ

Its disadvantages are that in brackish water it is inert and does not emulsify that it kills fish that it deteriorates on exposure and that it rapidly loses its toxicity after mixing with water containing algæ and other organic matter[34]

This larvicide was used largely during the construction of the Panama canal Le Prince[369] notes that it was very effective when added to crude oil in the dilution of 5 to 10 per cent In the

Canal Zone at present, however, only crude petroleum (fuel oil) is used[10].

(g) *Crude Carbolic Acid.*—The use of this substance as a larvicide was advocated by Wise and Minett[291] in British Guiana, for the treatment of small depressions holding temporary water. It was used in a final dilution of 1 in 16 000. The crude acid, containing cresol resolic acid and various oily and tarry substances, was found much more effective than the purified product. It was not, however, found suitable for use with a sprayer, because some of the constituents are not soluble.

(h) *Creosote*, in the proportion of 1 in 4 million parts of water, is stated to be an efficient larvicide and has been used in Italy[262], and in the U S A[31].

(i) *Commercial Borax* in the strength of 0 3 ozs. to 10 pints of water is recommended by Matheson and Hinman[256] as a cheap and practical larvicide for use in cisterns, rain water barrels and any container for water used for other purposes than drinking, and in pools where the plant and animal life is of little importance.

(j) *Lime.*—Borel[231] found that mosquitoes did not deposit their eggs in water receptacles coated inside and out with milk of lime, though the pH value and calcium carbonate content of the water was not inhibitory to the development of eggs, nor was the microscopical algæ necessary for the development of the larvæ reduced. He concluded that the factor which repelled the adult female was solely the white colour of the containers. These should be limed at least once a month in order to keep them quite white.

(k) *Soap.* This is an effective larvicide, its great disadvantage being its high cost. Balfour* suggested that marine soap, which is manufactured in large quantities in Marseilles, might prove of practical utility. Strickland[281] has experimented with this, but has found that in laboratory experiments the treatment of 4 square feet of water 1 foot deep would be 18 times more costly than by kerosene, whilst the treatment of a pool with 48 square feet of

* *Trans Roy Soc Trop Med and Hyg.* XVIII, 4, pp 155 156 (1924)

surface and only one inch deep would still be 4 times as costly with soap as with kerosene He found also that in field experiments the soap was less effective than in the laboratory

There is one way, however, in which the larvicidal properties of soap may be used in the tropics viz, 'dhobies' may be encouraged to wash clothes at the head of streams harbouring anopheline larvæ

(l) '*Paristan*' is a proprietary preparation which has been put forward as an efficient and cheap larvicide The Schuurmans[392] however, reported unfavourably on this substance, *finding it ineffective even in quantities 6 times as great as those* prescribed

(m) '*Isotex*' is another proprietary larvicide, recommended for use in swamps polluted pools, etc It is a dark brown fluid, *forming a thick film* on the surface of water, adhering to any surface even glass and staining clothes Feegrade[61] found *that in natural breeding places of about 72 square feet of* water surface 1 to 2 feet deep, with much aquatic vegetation at the margins 30 c c of the larvicide destroyed all aquatic life in 75 minutes He concluded that it is a powerful larvicide, but unsuitable for general use because it is fatal to fish

(n) '*Empranin*' is a proprietary larvicide, which has been used with success in Bengal It is claimed that 6 ounces of concentrated Empranin No 2 (special quality) will suffice for a water surface of 2 000 square feet Clyde[22] used this larvicide in anti malarial work during the construction of the Sarda Canal Headworks United Provinces, India, but its use was discontinued on account of its greater expense, as compared with that of fuel oil

(o) *Emulsified Necrosene* is a proprietary preparation containing approximately 90 per cent of oils, including creosote, turpentine and kerosene, and 5 to 8 per cent of soap It is claimed for this preparation that its lethal effect on larvæ will persist for four to six months following a single application in a final dilution of from 1/15 000 to 1/25 000

(*p*) *Hycol* a preparation derived from coal tar and closely resembling *creolin*, has been used with success in the Belgian Congo and in South Africa *Sal hycol* is another product of the same firm designed for use in brackish or hard waters

A very large number of other chemicals have been used for larvicidal purposes, amongst which may be mentioned various fluorine compounds potassium permanganate, mercurous and mercuric chloride, lithium chloride oxalic acid, salicylic acid, potassium cyanide naphthalene arsenic trichloride, copper, iron and sodium arsenate saprol waste sulphite liquor from paper mills waste products of sugar cane crushing etc Mention may also be made of experiments by Williamson[290] as to the effects of gases and vapours on mosquito larvæ in wells (formaldehyde, sulphur dioxide chloropicrin chlorine, steam etc)

(See *Bibliography*, Nos 249–291)

5. Sulphate of Copper.—This has been used for many years for inhibiting the growth of algæ in reservoirs For this purpose it is usually employed in a final dilution of 0 1 to 0 25 parts per million of water though this is not sufficient to destroy all forms of algæ Senior White[8] has shown that certain species will grow even in a dilution of 1 in 10 000 of copper sulphate As an anti mosquito measure this chemical is usually used in a final dilution of approximately 1 in 500 000 with the object of destroying algæ and thus diminishing the food supply of the larvæ This amount was found satisfactory by Kligler[99] in Palestine

The method of application is to place the required quantity of ordinary commercial crystals of blue vitriol' in a gunny bag or wire basket attached to a rope and draw it backwards and forwards in the water at the stern of a rowing boat Owing to the poisonous nature of the chemical its use cannot be left to the ordinary coolie It needs intelligent and careful supervision Small fish may be killed by copper sulphate in dilutions of less than 1 part per million of water[103]

A disadvantage which is sometimes met with is the odour produced by the decaying algæ after they have been killed, which

(ii) For paddy fields wells small ponds etc
Chela
Haplochilus
Polyacanthus

(iii) For salt or brackish water ponds etc
Therapon
Polyacanthus

Most observers in India appear to agree that the various species of *Haplochilus* are the most useful destroyers of mosquito larvæ *H panchax* (Piku) and *Anabas scandens* (Khajura the climbing perch) have been used in the wells in Bombay for many years The former was the species tried by Aitken in some of the Bombay fountains and called by him scooties Sewell and Choudhuri [14] stated that none of the species of *Chela* are surface feeders and that *Rasbora daniconius* is a purely vegetable feeder but Wilson[17] says that both these statements are incorrect

As regards the area of surface that can be kept free from larvæ by fish Sewell and Choudhuri[14] state that in the case of *Haplochilus* three specimens were sufficient in captivity to prevent larvæ developing in a small aquarium having a surface area of 1¼ by 2½ feet

Requirements for larvicidal fish

(i) They must be small so that they can get about in shallow water among weeds etc

(ii) They must be hardy and flourish in both deep and shallow waters

(iii) They must be able to breed freely in confined water areas

(iv) They must be able to stand transport and handling

(v) They must be difficult to catch and able to escape their natural enemies including man

(vi) They must be absolutely worthless and insignificant as food

(vii) They must be top feeders and carnivorous

Limitations of fish in the control of mosquito breeding

There are certain disadvantages in the use of fish as a control measure —

(i) Fish are only effective if present in sufficient numbers

(ii) They are only completely effective in the absence of all weed and floating débris

(iii) Small boys can be relied upon to catch them if they get the opportunity

(iv) Over zealous persons are apt to introduce other and larger species which may prey on them

(v) If there is not a sufficient food supply for them e g, in wells they will eat their own young so that breeding places must be periodically re stocked

(vi) Constant inspection is needed to see that the fish are flourishing and are in sufficient numbers and that the water is free from horizontal vegetation and floatage

(vii) In order to carry out these inspections and to keep up a sufficient stock of fish for the various breeding places a special staff is necessary

For these reasons the use of fish as a measure of malaria control though useful in certain conditions e g in places where for some reason it is impossible to employ any other measure, cannot be said to hold a position of very great importance in India

(See *Bibliography* Nos 196–217)

8 Introduction of Deterrent Aquatic Plants.—(*a*) Those which act by covering the water so thickly as to prevent the respiration of larvae e g the *Lemnaceae* Adie[117] in India recommended the use of *Lemna minor* for this purpose Certain species of *Azolla* a duckweed with a fern like leaf have been cited as a means of preventing mosquito breeding by MacGregor[141], Mühlens[149] França[135] and others though experiments by Smith[102] in America suggest that this plant is of little value Bentley[122]

stated that he had found both *Lemna* and *Azolla* of little value, but that *Wolffia arhiza*, which occurs in the form of small bright green round grains, without stem, roots or leaves, appears to be a useful preventive *Anacharis alsinastrum*, or American duckweed, and *Trapa bispinosa* or water nut plant (*singhara*), have also been said to inhibit larval development

The use of the water hyacinth (*Piaropus crassipes*) has been advocated by Viosca[153] in America Barber and Hayne[121], however came to the conclusion that it was of little value, and in any case on account of the disastrous effects of this plant in choking waterways it may be dismissed as a practical method of mosquito control

(*b*) Those which act by entrapping larvæ, e g , the aquatic carnivorous plants such as the *Utricularia*, or bladderworts The bladders of these plants have a valve like door, through which mosquito larvæ and other aquatic animals enter when searching for food or seeking to escape from their natural enemies It is said also that a member of the sundew family (*Aldrovanda vesiculosa*) which grows submerged in water, captures mosquito larvæ[24]

(*c*) Those which are actively poisonous to larvæ In 1919, Caballero[130] reported that the presence of *Chara fœtida* in collections of water prevented the breeding of mosquitoes Subsequent experiments by various workers with different species of *Chara* have led to conflicting results, the majority (e g , MacGregor[142], Hacker[350], Fisher[339], Barber[120], Blow[123], Buxton[60] and Hamlyn Harris[63]) being unfavourable Matheson and Hinman[145], however, found that pools in which *Chara fragilis* was growing were free from mosquito larvæ, and are of opinion that its introduction in temporary and permanent pools, slow flowing streams, marshy areas etc , might prove of practical value in anti mosquito work As to the method by which *Chara* produces its inhibitory effect, Caballero[130] thought that it was due to asphyxiation by an oily substance exuding from the plant on to the surface of the water, whilst Matheson and Hinman[146] suggest that it may be due to the presence of large amounts of oxygen given off by the

plant and oxidizing organic substance in solution thereby making this type of food unavailable for larvæ. They also found that dried *Chara* showed a marked lethal action, indicating the presence of some toxic substance.

Another member of the *Characeæ* *Nitella phauloteles*, was stated by Buhot[129] in Queensland to prevent mosquito breeding, but Hamlyn Harris[137] found 3 species of mosquitoes breeding freely in water in which this plant was growing. The latter observer found that a species of alga *Cladophora holsatica* inhibits larval growth and suggests that this may be due to the production of a narcotic poisonous gas.

Boyd[8] states that in Brazil he never found mosquito larvæ in marshy areas in which the swamp lily or wild ginger (*Hedychium coronarium*) grew. Hildebrand[105] notes that in the U.S.A. anopheline larvæ are rarely found in water where smart weed (*Polygonum* sp.) is growing in abundance, whilst Purdy[79] attributed the absence of anopheline larvæ in a rice-field in California to the presence of a blue green alga of the genus *Tolypothrix*.

With the possible exception of the duckweeds which might be useful in the case of disused wells etc. it cannot be said that at present there appears to be any indication that the introduction of deterrent plants will prove of much value as a practical measure of mosquito control.*

(See *Bibliography* Nos 117-153.)

9. Biological control of mosquito breeding.—In 1911 Watson[91] drew attention to the fact that in certain localities Nature has carried out in the most successful way a method of so altering the composition of the waters of the hills that the carriers of malaria no longer find it suitable for their existence and malaria practically does not exist. He suggested that researches into this question might reveal some way of

* The question of planting shade-giving plants and trees as an anti-larval measure in the case of species of anophelines which prefer sunlit breeding places has been discussed on p. 36.

opened at intervals, thus altering the level of the water and flushing out the lake

Where permanent measures cannot be carried out, the best way of dealing with such breeding places is by dusting them with paris green by means of a rotary blower, or from an aeroplane, in the case of very extensive swamps

2. Salt-water Swamps.—As far as India is concerned the problem in this case is limited to the coasts of Burma, Bengal and the Andamans, where *Anopheles ludlowi* occurs This species breeds in pools which are reached by the spring tides, but are not washed out daily by the neap tides It is in places where artificial bunds have been constructed that most breeding occurs The ideal solution is to reclaim the swamp by dredging or hand filling and where a comparatively small swamp exists in the vicinity of valuable land, e g , near a town, this may be a paying proposition To reclaim an extensive swamp with the sole object of protecting a small village is usually out of the question for financial reasons, and here the only alternative is often to remove the village to another site

Where there is sufficient tide, the installation of automatic sluice gates (such as the Calco gate) in the bunds may be effective[177]

In Panama it has been found that the larvæ and pupæ of the local malaria carrying anophelines will cease to develop if strongly saline water is introduced into their breeding places By digging parallel ditches at about 200 feet intervals, and providing a free opening into arms of the sea at each end of the ditches, it has been found possible to eliminate nearly all the breeding in the vicinity of Colon and the adjacent military stations The ditches are made of such depth that they contain water even at low tide (Chamberlain[163])

As in the case of fresh water swamps and marshes, if permanent measures are impossible on account of the cost, as is often the case, the best method available is dusting with paris green.

In the case of the great salt marsh districts in America, it has been suggested that mosquitoes may be attacked by the use of poison gas mixed with smoke clouds The practical utility of such a method is very doubtful on account of the possible danger to human and animal life involved by its use

3. Lakes and Reservoirs.—It will probably be found impossible to drain lakes in most cases though if this is done valuable land may be made available for cultivation The margins should be kept free from vegetation or may be treated with paris green from a boat by means of a rotary or electric blower If there is a narrow outlet to the lake it may be possible to install a dam with a sluice by which the level of the water may be raised and lowered at intervals Good results have been recorded in the U S A by the use of this method in the case of impounded waters

The level of the water is kept as high as possible during the non breeding season in order to kill the land vegetation up to this level The drift and floatage accumulated during this period is chiefly collected along the margins of the reservoir At the commencement of the breeding season the level of the water is lowered as much as possible to strand the floatage and drift This kills the larvæ in the floatage and leaves a clean water's edge round the reservoir After this raising and lowering of the water level is carried out at frequent intervals (less than two weeks) throughout the breeding season Dragging operations must supplement fluctuation where heavy central floatage is present

(*See Bibliography* Nos 161 162 166 169, 185, 191)

4 Ponds and Tanks.—It may be impossible to drain or fill these on account of the cost or because they form the only water supply The following measures may be tried —

(*a*) The pond may be regularly dusted with paris green.

(*b*) Vegetation and overhanging branches may be removed from the margins

(*c*) Copper sulphate may be used, to get rid of algæ (*see* p. 77).

(*d*) For bigger weeds a sub aqueous saw may be used This is a long band of steel with a *double saw edge*, weighted with lead, and with a rope attached at each end A man on either side of the pond pulls the rope, thus cutting the weeds[269]

(*e*) One end of the pond may be deepened, so that when the water falls there will be a good place for fish, with which the pond may be stocked, if they are not already present It is a good plan to sink a barrel in the deepest part of the pond to furnish a retreat for the fish during droughts

(*f*) If the outlet can be controlled, the water level may be raised and lowered as in (3)

Of the above methods the use of paris green is probably the most effective, most economical, and most easy to apply

5. Large River Beds.—These are usually very difficult to deal with Good may be done, however, by draining pools into the main stream, filling in pot holes and clearing vegetation Pools left behind after the subsidence of floods may be treated with cresol, or with paris green

6. Small Streams.—The ideal to be aimed at is that the stream should have steep banks directly above and below the flow line uniform grade and width, and a straight course, and be free from grass, sticks, stones, or other obstructions which would interfere with the current With these objects in view the course may be straightened out where possible and the bottom regraded in places, so as to confine the water within narrow banks and increase the rate of flow In places where there are embayments a channel may be constructed with a line of stones or stakes, the space behind being filled with earth and stones rammed down Vegetation along the bank should be cut away, and the banks themselves sloped to an angle of about 45 degrees Pot holes in

stream beds may be filled with stones and pools emptied by draining them into the main stream Where the bottom of the stream is soft so that there is a tendency for the formation of large pockets in the channel stone may be rammed into place to prevent further excavation[18]

In certain cases dams may be installed with sluices which may be opened at intervals to flush out the larvæ Watson[45] in Malaya treated hill streams with success both by subsoil drainage and by oiling Dusting with paris green may also be practised

7. Hill foot Seepages. These are best treated by constructing a system of hill foot contour drains to catch the seepage at the point where it arises (Fig 13) These may be either open or subsoil drains if open regular oiling will be necessary Occasionally it may be possible to deal with seepages on the banks of a ravine stream by damming the ravine and submerging the springs[78]

8 Rice-fields.—These are in themselves rarely dangerous except in hilly tracts where water is in continuous motion through the fields The cultivation of rice in the beds of streams in such districts by making small artificial bunds is especially dangerous The problem is a difficult one and the only really satisfactory solution would appear to be a change in the method of cultivation brought about by improved education in agriculture or by law Drying off of the fields throughout a tract on one day of each week has been legally imposed in Java As regards temporary measures the employment of paris green which does no harm to the crop is the most useful at our disposal Uncultivated plots in terraced fields which are allowed to become flooded are especially dangerous and may be treated by oiling[79]

It has also been suggested that the problem of mosquito breeding in rice fields may be open to attack by biological methods and investigations in this direction have been made by Williamson[80] Purdy[79] and others (see p 83)

9 Irrigation Channels and Ditches.—These are important sources of anopheline breeding unless they are properly looked

after No leakage should be allowed from them and their margins should be kept free from vegetation It should also be seen that no pot holes are present in the beds of such channels as these will form breeding places when water is not flowing through them It is however, difficult to enforce regulations to this effect, and the best way of dealing with them in most cases is probably regular treatment with paris green

10. Irrigation and Water-logging.—The term 'water-logging as defined by Gill[170], is confined to areas where owing to the height of the subsoil water the superimposed soil is kept permanently damp by moisture derived from the subsoil, as contrasted with false water logging' which refers to dampness of the soil caused by the presence of an impermeable stratum preventing for a considerable time the downward percolation of rain water

The question of the influence of irrigation and water logging on the incidence of malaria is a complex one, and its aspects differ widely in different localities In India, in the Punjab it has been *repeatedly shown that where canal irrigation gives rise to water* logging a grave degree of endemic malaria associated with a *constantly high spleen rate results*[171] *Here, irrigation if unac*companied by adequate drainage schemes will tend to raise the level of the subsoil water *and favour the formation of swamps*, whilst by raising the relative humidity of the atmosphere it will create conditions favourable for mosquito life The conditions in Bengal on the other hand are entirely different Here the country is low lying and it has been observed that areas which are regularly flooded are the least malarious whilst those protected from flooding by embankments suffer most Bentley[158] holds that the adoption of a comprehensive scheme of inundation irrigation from the main rivers would be an effective method of controlling the incidence of malaria in this part of India

11. Depressions in the Ground should be filled in where possible For this purpose *town rubbish may be used, covered* with a layer of earth Care must be taken that no potential water

containers such as old cans etc, are left exposed. The work should be done preferably in the cold weather to avoid the breeding of flies Where water is present the rubbish may be shot into it at any season provided it is not allowed to project above the surface, for dangerous anophelines will practically never breed in water thus fouled Otherwise in summer the rubbish should be dried and burnt and the ash used to fill in the depression Cinders, sawdust and waste products from factories may be used when available

12. Borrow-pits.—These are usually harmless when first excavated except where they tap seepage springs It cannot be seen whether this is the case after rain, and therefore in foot hill localities even fresh pits should be treated as dangerous Old borrow pits containing vegetation frequently form dangerous breeding places A row of borrow pits may be drained into one pit so that there remains only a single pool to deal with This may then be treated with oil or paris green or may be drained by driving a vertical shaft through an impervious stratum In the case of borrow pits alongside railway lines those near stations may be filled with ashes etc None should be allowed within distant signals of stations (Senior White[83]) In certain cases it might be possible to treat a row of borrow pits by the side of a railway line by running a trolley along it and dusting them with paris green

13. Small Pools formed by showers of rain may often be brushed out with a broom dipped in oil If too large for this, they may be treated with oil balls or paris green

14. Holes in Rocks and Trees may be filled with earth or gravel or with cement In the case of trees the cement may crack and it is probably preferable to use asphalt

15. Wells.—The only completely satisfactory method of dealing with wells, short of actually filling them in is to provide them with a cement-concrete cover with, if desired the provision of a pump Trap-doors should be avoided as even if they are

mosquito proof when first installed they soon become ineffective from the effects of constant use and warping Moreover they are very frequently left open at night"[56]

The use of petrol in wells was recommended by Ryles and Majumdar[371] in the strength of 24 ozs per 80 square feet of water surface (*see* p 51) Liquid paraffin might also be employed the water being withdrawn by means of a pump

Hackett[417] suggested the use of paris green stating that in the strength of 1 gm to 20 square metres of surface its use is quite safe Experiments in this direction have been recently carried out in Bangalore There are however objections to placing even a harmlessly minute amount of an arsenical preparation into drinking water apart from the fact that in India there is frequently violent opposition to any interference with wells on religious grounds

Experiments have also been made by Williamson[290] as to the larvicidal effect of various gases and vapours in wells

In the case of disused wells *Lemna* or *Wolffia* may be introduced with the object of forming a dense growth on the surface and preventing the respiration of the larvæ

Wells may also be stocked with larvæ eating fish (*see* p 79)

16 Cisterns—These should be covered either with sheet iron or cement concrete Corrugated iron covers are unsatisfactory and should not be permitted The man hole should be circular and provided with a cap cover fitting over a rim round the opening The cover of the man hole should be kept locked Inlet pipes should be fitted with check nuts and should never enter the cistern through the man hole Overflow pipes should be provided with a perforated cap of brass or copper The use of valve boxes should be discouraged where possible as their covers are rarely if ever mosquito proof The work of inspecting cisterns to see that they are in a mosquito proof condition is greatly aided if each cistern is clearly numbered with white painted figures at least one foot high"[56]

17 **Fire buckets** may be treated with cresol or lime

18 **Rain water gutters** along the eaves of houses are often sources of mosquito breeding A gradient of at least one inch in 24 feet is sufficient for large buildings provided the slope is a permanent one which is ensured by making the gutter with a gradually increasing depth towards the outlet[55] If there is any part in which the water stagnates it may be dealt with temporarily by boring a hole at the most dependent point The ideal solution and that usually adopted in yellow fever campaigns is the total prohibition of all rain water gutters

19 **Water used in Building Construction** —Mention has already been made of the amount of anopheline breeding which may occur in the water which is poured on to the surface of cement-concrete whilst it is setting This may be treated with cresol (*see* p 73) Breeding may also occur in the water receptacles used for soaking bricks used in building Unless it can be ensured that these receptacles are emptied daily after use cresol may be applied in this case also[258]

20 **Stand pipes and Hydrants** —If these cannot be connected directly with the main drainage system a useful plan is to construct soakpits two to three feet in diameter and about one foot in depth round each The pits may be filled with stones or broken brick covered with a layer of gravel Another method is by alternation of flow Two drains are dug leading away from each stand pipe the water being finally allowed to flow over the surface of the soil or to irrigate a plot of ground Each drain is used for a few days at a time whilst the area supplied from the other is allowed to dry up (Sergent and Sergent[41])

21 **Leaking Sluice valves** —These may be dealt with by filling the valve chambers with sand to the requisite level

PART IV.

RECENT ADVANCES IN MALARIA CONTROL

In the following pages an account is given of the more important developments in malaria control which have been introduced during the period which has elapsed since this book was first published The various measures discussed are dealt with in the same order as in the *original edition*

A —PROTECTION AGAINST BITES OF MOSQUITOES

1 Repellents —In the U S A the New Jersey pyrethrum larvicide has been extensively used as a spray applied to grass bushes etc for the protection of outdoor gatherings against the attacks of adult mosquitoes The formula for the stock solution is given on p 110 This is diluted with 10 to 12 parts of water before spraying and is said to afford protection from mosquito annoyance for a period of several hours (Ginsburg[1011], Vannote[1020])

The anti mosquito pomade referred to on p 4 as Dover's formula is now widely used in India and has been adopted in a slightly modified form by the Army for use under field conditions

(See *Bibliography* Nos 1011–1020)

2. Screening —A number of papers have been published regarding the maximum size of mesh permissible for the exclusion of mosquitoes in different parts of the world Mulligan and Majid[1035] concluded that 14 mesh and 28-30 S W G (aperture 0·055 to 0 057 inch) was the optimum for general use in India Hargreaves[845] found that 14 mesh and 30 S W G (aperture 0 059

inch) excluded *A funestus* in Uganda, but Davey and Gordon[1026], working in West Africa, recorded that both this species and *A. gambiæ* could pass through this size of opening, and that some specimens of *A funestus* escaped through apertures as small as 0 050 inch They considered that the maximum size of aperture advisable for screening houses in West Africa against anophelines was 0 047 inch, represented by a standard screen cloth of 16 mesh and 28 S W G The same authors described the method by which mosquitoes make their way through narrow apertures, and concluded that their ability to do so is limited by the dorso-ventral diameter of the thorax, confirming in the main the original observations of Russell and Nono[1037].

(See *Bibliography*, Nos 1021–1039)

B—MEASURES DIRECTED AGAINST ADULT MOSQUITOES

1. Traps.—Traps are rarely used as a measure of mosquito control, but a combined method of fumigation and trapping has been employed for this purpose in barracks in India (James[808]) A piece of black cloth, with a central opening 2 feet in diameter, is stretched over a window The mouth of a muslin bag 6 feet long is sewn round the margin of the opening and the bag itself is passed through the window and attached to the verandah posts, or other available support The door and the remaining windows are closed and curtained, and the room fumigated by burning pyrethrum coils The mosquitoes fly towards the opening in the cloth, which is now the only source of light, and are caught in the bag

Mechanical traps, with light as the source of attraction, fitted with electrically operated suction fans, have been used extensively in the U S A for experimental purposes A similar apparatus, equipped with a mercury vapour lamp, has been widely advertised in India in recent years for the control of mosquitoes Several papers recording observations with this machine have been published, but the authors are generally agreed that its high cost

and limited sphere of action renders it ineffective as a method of malaria prevention (Wats and Bilderbeck[1107], Senior White[1104], Syddiq[1106])

(See *Bibliography* Nos 1084–1108)

2 **Sprays** —The spray killing of adult mosquitoes is now recognized as a major control measure and in the opinion of the author the development of this method represents the most important advance which has been made in malaria prevention in recent years

Swellengrebel[10] * and *his co workers in Holland have used* the method for many years but it was not adopted extensively in the tropics until the publication of the remarkable results achieved with pyrethrum sprays in rural areas in South Africa from 1932 onwards (Ross[1066], de Meillon[1060] Booker[1064]) It *has been widely used for controlling malaria in native huts in* Natal and Zululand and for the protection of railway and other employees and has been found especially effective in combating outbreaks of malaria in epidemic form Thornton[1075] has drawn attention to the fact that the effects are produced not by a diminution in the number of *anophelines but by a reduction in* their rate of infection which may be very marked a fact which has been confirmed by our experiences in India

Spray killing of adult mosquitoes was brought into use in Delhi in 1936 when the quarters occupied by four communities of Government employees living in particularly malarious sections of the urban area were regularly sprayed throughout the malaria season (Covell Mulligan and Afridi[1048]) The results were so striking that the method was immediately recommended for use throughout India as being particularly suitable for personnel such as police railway forest or other Government employees and labour forces on estates mills and other industrial enterprises where housed in permanent quarters It was at first thought that the usefulness of this method would be limited to such conditions but in 1937 it was introduced as an experimental measure

in two villages on the outskirts of Delhi The results were so encouraging that it has since been extended to a number of other villages in Delhi Province

Reports on the efficacy of the spray killing of adult mosquitoes from employers of labour railway authorities and Government officials from all parts of India have been universally favourable, and Russell and Knipe[1008] have reported that this method has had a marked effect in reducing malaria transmission in a typical South Indian village

Further tests on the various locally prepared mixtures which have been recommended as sprays and on a number of the proprietary preparations now on the market have shown that those which contain pyrethrum are invariably far more efficacious than the others A very effective spray can be prepared by merely soaking one pound of dried pyrethrum flowers, previously powdered in 1 gallon of kerosene oil for 72 hours provided that the flowers are of good quality It may however be found more convenient to use one of the trade extracts of pyrethrum (e g *Pyagra Pyrocide Pyefly Pyrentol* etc) which are diluted with kerosene oil before use

Pyrethrum cultivation on a commercial scale was formerly almost entirely confined to Dalmatia and Japan but in recent years it has become an important industry in Kenya It is now being grown in several localities in India (Kashmir North West Frontier Province Punjab, Nilgiri Palni and Cardamom Hills) and flowers from all these sources have been shown to possess excellent mosquitocidal properties It is expected that an ample supply of Indian grown pyrethrum will shortly be on the market so that an effective mosquitocide will be available throughout the country at a comparatively low price (Covell[104*])

The efficacy of the method is in direct proportion to the frequency of its application In areas where the infection rate among the carrier species of anopheline is low, good results have been recorded by spraying once a week only Where the infection rate

is high it is advisable to spray twice or even three times a week throughout the malaria season It is seldom possible to spray more often than this on a large scale but in very malarious localities residents should be encouraged to spray their living rooms and those of their servants daily while transmission is at its height especially when a case of malaria has actually occurred on the premises or in the immediate vicinity Particular attention should be directed to the spraying of rooms occupied by young children and infants who constitute the chief source of infection for mosquitoes

The spray should be mixed by a responsible person to minimize the risk of theft All apertures should be closed as far as possible before spraying and should preferably remain closed for 20 minutes thereafter Pieces of sacking old blankets sheets etc are useful for this purpose If there are any cowsheds stables or other attractive shelters for mosquitoes nearby these should be sprayed also

The amount to be sprayed in any particular case can only be determined by actual trial For a room in the usual type of menial quarter or village in India (capacity about 1 000 cubic feet) half an ounce of the diluted mixture is usually sufficient but this may have to be increased if any apertures remain unclosed The fact that rooms cannot be completely sealed is by no means an indication that spraying will be ineffective and excellent results have been achieved under such circumstances by using rather more of the spray than would otherwise be required

Regular spraying should be commenced when the local carrier species of mosquito begins to enter the houses at least a fortnight before the malaria season is expected to start and should be continued throughout the transmission period The most suitable time of day for spraying is in the early morning before cooking has commenced The personnel employed should be recruited from among the local residents and it is best to engage for this purpose boys of under 14 years of age as there is not

likely to be any objection to them entering rooms occupied by women. The exercise of tact is necessary in introducing the method but once the routine has been established, it is invariably *found to be extremely popular among the persons concerned*. After a while it may be found possible to leave the actual spraying to the local inhabitants but *periodical supervisory visits are essential* for it is the universal experience of sanitarians that the individual if left entirely to himself will seldom lift a finger to safeguard his own health, or that of his family.

Hitherto the chief difficulty in applying the method has *been the lack of a suitable type of sprayer*. For small rooms the hand sprayers or atomizers obtainable everywhere at a trifling cost are useful but they are not very durable and are uneconomical in use. Far the most effective apparatus at present available is an ordinary power spray painting machine driven either by an electric motor or a small petrol engine. These are especially valuable for use in large buildings such as barracks.

As regards costs the expenditure in the Delhi villages in 1937 worked out at one anna per head per month. This does not include the salary of the officer in charge who would normally exercise supervision over a number of villages. The costs given by Russell and Knipe for 7 months spraying in a Madras village amounted to Re 0-15-3 per head. In South Africa Thornton reported the cost of spraying for 6 months at £ 0-2-5 per hut. De Meillon states that the spray killing of adult mosquitoes proved only one third as costly as that of larval control measures conducted over the same area of operations.*

Two great advantages of spray killing of adult mosquitoes are (i) it is the only anti-malaria measure which is universally

* This method is sometimes employed to destroy potentially infective mosquitoes during the winter months. This has no appreciable effect on the numerical prevalence of mosquitoes during the following summer, a finding which is in agreement with S. P. James' original observations regarding winter larval control in Mian Mir (*Sci. Mems. Govt. Ind.*, No. 6, 1903). Cold weather control of mosquito breeding has however been advocated in recent years by Rice in Assam.

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popular among the persons whom it is designed to protect, and (ii) it is the only anti malaria measure which can exert an *immediate* effect on the course of an epidemic In India, the fact that pyrethrum of high quality can be grown in a number of different localities makes it certain that the cost of the spray will eventually be greatly reduced, and that its use will be widely extended *in future years*

The spraying of aircraft with pyrethrum insecticides has been practised as a routine measure for some years as a yellow fever control measure in America Africa and India (Whitfield[1080])

(See *Bibliography*, Nos 1040–1083)

3 Zooprophylaxis —A number of puzzling problems connected with this subject have been clarified in recent years by the discovery that a single species of anopheline may be made up of a number of varieties, or subspecies which, though apparently identical are biologically distinct differing widely in their habits and food preferences In Europe, *A maculipennis* is now known to comprise at least six forms, two of which, *typicus* and *melanoon* have but little contact with man whereas two others, *labranchiæ* and *sacharovi* habitually enter houses, whilst the remaining two *messeæ* and *atroparvus*, are easily diverted by domestic animals but overflow into human habitations in search of food under certain circumstances *Typicus*, *messeæ* and *melanoon* are associated with malaria only in exceptional circumstances, *labranchiæ* and *sacharovi* are invariably dangerous vectors, whilst *atroparvus* occupies an intermediate position being as a rule not dangerous but capable under certain conditions of becoming a carrier of considerable importance (Hackett and Missiroli[1115]) * The various varieties, or subspecies are distinguishable by certain differences *in the pattern of the egg*

* It should be noted that the term *anthropophilous* as applied to biological races of mosquitoes in Europe denotes those which attack man and animals indiscriminately *zoophilous* indicates races which attack animals by preference

In India *A fluviatilis* in the Wynaad district of Madras Presidency is a most dangerous malaria carrier feeding freely on man, whilst an apparently identical species in the Terai area of the United Provinces is almost exclusively a cattle feeder and is relatively harmless. Sweet and Rao[1136] have described a variety of *A stephensi* distinguishable from the type form by the characters of the egg and probably biologically distinct. It appears likely, on epidemiological evidence that other species e g, *A culicifacies* may likewise include more than one biologically distinct variety or subspecies (Senior White[1135])

These observations have explained certain problems which were previously obscure as for instance why one locality is malarious whilst another where the anopheline fauna is apparently the same is non malarious and it has been suggested that further study of the various biological strains may lead to a method of species control whereby relatively harmless races may be substituted for dangerous ones. Hitherto however there has been little indication that animal prophylaxis is likely to become an important measure of malaria prevention

(See *Bibliography* Nos 1109–1148)

4 Housing and Malaria —The suggestion has sometimes been made that the incidence of malaria might be diminished if human sleeping quarters were rendered unattractive as resting places for anophelines but the investigations of Barber and Rice[6] lend no support to this view. There is no evidence that the occupants of a house suffer from malaria in proportion to its attractiveness for mosquitoes for the daytime resting places of these insects afford no indication as to where they are likely to be found at night. Christophers and Missiroli[62], in a comprehensive review of the subject concluded that the only effective method of controlling malaria through housing was by

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The spraying of aircraft with pyrethrum insecticides has been practised as a routine measure for some years as a yellow fever control measure in America Africa and India (Whitfield[1090])

(See *Bibliography*, Nos 1040–1083)

3 **Zooprophylaxis.**—A number of puzzling problems connected with this subject have been clarified in recent years by the discovery that a single species of anopheline may be made up of a number of varieties or subspecies which, though apparently identical are biologically distinct, differing widely in their habits and food preferences In Europe, *A maculipennis* is now known to comprise at least six forms two of which *typicus* and *melanoon* have but little contact with man, whereas two others *labranchiæ* and *sacharovi* habitually enter houses , whilst the remaining two *messeæ* and *atroparvus*, are easily diverted by domestic animals but overflow into human habitations in search of food under certain circumstances *Typicus*, *messeæ* and *melanoon* are associated with malaria only in exceptional circumstances , *labranchiæ* and *sacharovi* are invariably dangerous vectors , whilst *atroparvus* occupies an intermediate position being as a rule not dangerous, but capable under certain conditions of becoming a carrier of considerable importance (Hackett and Missiroli[1115]) * The various varieties, or subspecies, are distinguishable by certain differences in the pattern of the egg

* It should be noted that the term *anthropophilous* as applied to biological races of mosquitoes in Europe, denotes those which attack man and animals indiscriminately *zoophilous* indicates races which attack animals by preference

In India *A. fluviatilis* in the Wynaad district of Madras Presidency is a most dangerous malaria carrier feeding freely on man, whilst an apparently identical species in the Terai area of the United Provinces is almost exclusively a cattle feeder and is relatively harmless. Sweet and Rao[1136] have described a variety of *A. stephensi* distinguishable from the type form by the characters of the egg and probably biologically distinct. It appears likely, on epidemiological evidence, that other species, e.g. *A. culicifacies* may likewise include more than one biologically distinct variety or subspecies (Senior-White[1135]).

These observations have explained certain problems which were previously obscure, as, for instance, why one locality is malarious whilst another where the anopheline fauna is apparently the same is non-malarious; and it has been suggested that further study of the various biological strains may lead to a method of species control whereby relatively harmless races may be substituted for dangerous ones. Hitherto, however, there has been little indication that animal prophylaxis is likely to become an important measure of malaria prevention.

(See *Bibliography* Nos. 1109–1148.)

4. Housing and Malaria.—The suggestion has sometimes been made that the incidence of malaria might be diminished if human sleeping quarters were rendered unattractive as resting places for anophelines, but the investigations of Barber and Rice[illegible] lend no support to this view. There is no evidence that the occupants of a house suffer from malaria in proportion to its attractiveness for mosquitoes; for the daytime resting places of these insects afford no indication as to where they are likely to be found at night. Christophers and Missiroli[illegible], in a comprehensive review of the subject, concluded that the only effective method of controlling malaria through housing was by screening.

C—MEASURES DIRECTED AGAINST LARVÆ OF MOSQUITOES

1. Drainage—In the history of malaria control there are numerous examples of the truism that a method suitable for one set of conditions may be ineffective or even deleterious in another. The divergent views expressed by malaria workers regarding the lay out of drainage systems are thus largely explicable by the existence of local differences in physiography and climate. For instance, Le Prince and Orenstein[34] as the result of their experiences in Panama, stated that the outlet of subsoil drains must be well above the body of water into which they discharge their contents. This recommendation, which was endorsed in the first edition of this book, has been stigmatized by Scharff[57] in Malaya as misleading and likely to lead to mistakes in design, since the placing of pipes too near the ground surface is a frequent fault. Again, whilst in Malaya great stress is rightly laid on the importance of securing the lowest possible outfall for drains in general, in Delhi the outfall of storm water drains is now placed at the highest possible level consistent with the provision of a satisfactory flow, in order to minimize the heading up of water *when the River Jumna is in flood*.

In recent years the choking of subsoil drains by the roots of trees and grasses has become a serious problem on rubber estates in Malaya, and in some instances a reversion has been made to the former system of open drains and oiling. Barrowman[4] recommends the provision of a double line of pipes in such circumstances, laid one above the other. The roots grow into the lower line first, and though the upper one too may ultimately become choked, it is claimed that the effective life of the system is thereby prolonged by at least sixfold.

A development of subsoiling which has yielded strikingly good results in Malaya is that known as *fascine drainage*, originally introduced by Scott[60]. A layer of sticks, each about 6 feet long and 2 inches in diameter, is placed in the bottom of the drain or stream which has been previously graded and straightened *the*

thickness of the layer depending on the depth of the drain and the amount of water to be disposed of. A series of layers of coarse grass (*lallang*), each overlapping the next below it like thatch on a roof, is placed over the sticks. Over this, the trench is filled with heavy earth. A modification of this method is to lay the sticks against the lower 6 inches or so of the sides of the trench, fixing them in place by vertical pegs. Other short sticks are laid crosswise, supported by the top layer of the lengthwise sticks. A layer of long sticks is now applied lengthwise as a roof to the channel, these being supported in their turn by the crosswise sticks. The work is then completed as already described*. It was originally expected that fascine drains would last only for a few months, but many of them are still functioning perfectly after a lapse of several years. It appears that in Malaya not only sticks which are continuously in water but also those laid in drains with only a seasonal flow, have astonishing powers of survival.

Subsoil drains with the channel made of flat stones as figured on p. 40 are also in common use in Malaya, e.g. for dealing with seepage outcrops in quarry pits, under the designation of *stone picking*. This method has also been found useful under similar conditions in the Ridge quarry pits in Delhi.

A method of drainage which has met with great success in Delhi is that known as the *lulo system*, which is employed when for financial or other reasons it is found impossible to remove water completely from a particular area. The entrance of extraneous water into the area in the form of river flooding or storm water is excluded by bunds if necessary, and the area thus protected is so dressed that all rain-water falling on it is directed into a single depression or *lulo*, which is deepened and widened for the purpose. In this way large numbers of breeding places are abolished, and the single remaining water collection can easily be kept

*This procedure is sometimes locally referred to as *herbage cover*, a term which should properly be reserved for the method described on p. 11[illegible].

clean weeded and effectively treated with larvicides or stocked with fish An important feature of this method is that whilst every *advantage is taken of the natural* slope of the ground no formal drains are constructed so that maintenance charges are practically non existent The *method is most effective in areas* where the annual rainfall is moderate in amount and it can be carried out for a fraction of the cost entailed by filling operations (Covell and Afridi[581])

Before leaving the subject of drainage particular *attention is* drawn to the value of turfing the sides of drains to minimize the effects of scour A special technique for planting and growing grass for use in anti malarial drainage projects has been described by Scharff[7 r]

(See *Bibliography* Nos 732-764)

2 **Oiling** —A number of important researches have been carried out in recent years regarding the method of action of oil on mosquito larvæ and the essential qualities required for effective larval control These have led to some modification of the generally accepted ideas on the subject *Allen*[805] sums up the present position as follows —

For a long time we have known that we want an oil combining high toxicity with low volatility (which may occur together but are not necessarily related) *low viscosity and good spreading* properties Recent studies the most important by Murray[900] seem *to establish the following* additional important points —

(i) Reasonable toxic properties are sufficient, the highest possible toxicity is neither necessary nor desirable

(ii) A perfect film is not absolutely necessary to ensure good results Small breaks in a film of good durability and toxicity do not permit the escape of larvæ

(iii) Volatility low enough to ensure a good film for a few hours is sufficient It is not necessary that the film should remain intact for several days

(iii) The aromatic vapour pressure and the aromatic-aliphatic ratio should be below the critical figure for film instability

(v) Spreading pressure should be between 11 and 35 dynes. A greater spreading pressure would be expected to produce too thin a film to be practical

(vi) The addition of special 'spreaders' to mosquito oils is in general not justified

In India *Malariol* a proprietary preparation specifically designed for anti larval purposes is now widely used and has been adopted by the Army authorities It is claimed that this oil has good spreading powers is highly toxic to larva (killing them within 15 minutes of application) and burns up the vegetation and grass amongst which the larvae shelter along the banks of breeding places to which it is applied It is however somewhat more expensive than the diesel oil-cresol mixtures formerly in general use and opinions differ as to whether the advantages claimed for it compensate for the increased cost One decided advantage of this preparation is that it is not likely to be stolen by unscrupulous employees

In Malaya much experimental work has been done to determine the relative efficacy of various mixtures of oils classed as heavy solar and light Heavy oils are those employed for diesel oil engines solar oils for lighter oil engines and light oils for lighting and cleaning purposes The effect of adding pyrethrum to such oils has also been tested and it has been shown that this has the effect of shortening the time in which the larvae are killed in all cases and that in the case of an oil with high boiling range (Diesel II) it also greatly increases the death rate

As regards methods of applying oil mention may be made of the *brush spray mop routine* introduced by Quaife[87] in Malaya for the treatment of streams and drains. A thin line of oil is sprayed on the water surface for four paces, and this is vigorously

distributed with a brush for 100 yards or more the coolies brushing rapidly with the flow of the water and taking care that all side pockets are treated The workers then proceed to the next oiling point 100 yards upstream and repeat the performance The spray coolie deals with any seepage or side channels encountered and finally all small ponds pot holes etc are treated by a mop dipped in oil For the sprayer the finest nozzle is used and work is abandoned if heavy rain occurs This method is claimed to be *both economical and effective* but constant *skilled* and intimate supervision is essential for its success

One of the most difficult problems in anti malaria work in India is the control of *larval drift* in streams and irrigation channels In Delhi for instance the Western Jumna Canal Tail Distributary is a prolific source of breeding of *A culicifacies* the larvæ of which were formerly carried down into the urban area in enormous numbers Oil booms of various designs have proved very effective in dealing with situations of this kind A considerable degree of ingenuity is required in designing such booms for whilst all larvæ must be held up by them the flow of water must not be obstructed Moreover they must be able to function equally well at varying water levels In the case mentioned above a boom has been erected across the canal a short distance above the point where it enters the urban area It consists of three sections each made of *sarkanda* (*moonj*) grass in the form of a chick which can be raised or lowered as desired the stems of the grass being parallel with the water surface When the water in the canal is low, only the central section is used whilst when it is full all three sections are brought into operation The boom is supported by stakes driven into the bed of the canal and *bhoosa* (chaff) soaked in oil is thrown on to the water above it so that the larvæ trapped by the boom are killed by the oil exuding from the *bhoosa* It is necessary to provide some arrangement for holding up objects which may float down the stream and damage the booms A single rope stretched across from bank to bank is usually sufficient for this purpose (Covell and Afridi[81])

All oil booms need a good deal of attention, and, wherever they are used some one responsible must be constantly on the watch, to prevent unauthorized persons from tampering with them But their use leads to economy in oil and they probably constitute the most effective method of dealing with the difficult problem of larval drift The type of boom suitable in any particular case will depend on local conditions

As regards sprayers the type found most generally useful in India is the knapsack sprayer (Vermorel Eclair or Four Oaks) operated by a hand lever located immediately beneath the right elbow This pattern is lighter less costly and less likely to get out of order than high pressure sprayers, and the coolie has no difficulty in regulating the amount of oil ejected from the nozzle

(See *Bibliography* Nos 905-911)

3 Chemical Larvicides *Paris green* —The use of this larvicide has been continued and extended in many European countries and in the U S A but in the tropics it is not generally employed as widely as had been expected when it was first introduced There are several reasons for this two of the most cogent being (i) that its application requires a good deal more intelligence and supervision than that of oil and (ii) that it has no effect on the larva of culicines the control of which is usually demanded by those who provide the necessary funds Consequently in most tropical countries the application of paris green is limited to situations where local conditions preclude the use of oil In Delhi for example it is found extremely useful for bringing under rapid control stretches of low lying ground which have been subjected to river flooding due perhaps to a breach in some embankment Other water collections are for the most part dealt with by oiling as a routine measure

The application of paris green from aircraft continues to be practised in the U S A to deal with mosquito breeding in impounded waters notably in the Tennessee Valley where the

shoreline will eventually exceed 7 000 miles one third of which will need protection (Watson and Bishop[709]) *This method is also em*ployed very extensively in Russia where in 1937 breeding places extending over an area of 12 000 square miles were treated It has been found particularly effective for dealing with peat bogs reed beds ricefields and cotton growing areas intersected by a network *of irrigation ditches* (Nabokov[978]) It has also been used in Madagascar (Legendre[969] Boyé[951]) Morocco (Sicault[909]) and Indo China (Morin and Martin[974]) In Delhi experimental dusting of paris green from aircraft was carried out in 1936 when it was thought likely that this might prove to be the only practicable method of controlling mosquito breeding in the low lying tract bordering the Jumna River The method proved effective but *expensive and it was ultimately found possible to deal with breed*ing in this area with greater thoroughness and at much less cost by other means (Covell and Afridi[581])

Barber and his colleagues[943] in Greece have describe a dustless method of applying paris green which has also been used in India (Russell and Jacob[990]) in Cyprus (Aziz[94]) and in Russia (Keiris and Klokov[965] Yurchak and Bozhenko[808]) A stock mixture is prepared composed of kerosene oil 400 c c paris green 200 c c and dry powdered egg albumin 1 gramme * which are poured into a Winchester quart bottle in that order The bottle is vigorously shaken a procedure which is repeated whenever any of the mixture is poured out A number of corked vials are provided into each of which 25 c c of the stock solution is poured before the coolie sets out on his round The vials are carried in a cartridge *belt which accommodates 20 to 25 vials each in a separate pouch* The coolie also carries a tin can of 1 litre capacity which when not in use is suspended from the belt and a funnel provided with a wire gauze sieve

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* In Delhi a mixture of kerosene oil ½ gallon paris green 2½ pounds castor oil 1 ounce and the whites of 4 to 6 eggs shaken up in a petrol can and used in the dilution of 1 ounce to 1 gallon of water has been found effective

On arrival at the scene of operations the coolie pours 2 litres of water into the sprayer from his tin can, filtering this through the funnel to remove débris He then adds the contents of one vial, after vigorously shaking it, washing the last remnants of the stock mixture into the sprayer with a little more water Three more cans full of water are added, making 5 litres in all to 25 c c of stock mixture The tank of the sprayer is agitated from time to time by a sway of the hips during the application of the spray One vial (i e 25 c c) of the stock mixture is sufficient for treating 700 to 900 square feet of water surface and an average Indian coolie uses the contents of 20 to 25 vials per working day (Russell and Jacob[990] Russell, Knipe and Rao[991])

The advantages claimed for this method are that there is no need to store or transport the diluent that very little paris green is lost by sinking as it is kept afloat by the kerosene, and that there is no dust left on the water surface to block the feeding of the larvæ which last consideration may explain why so little paris green is found necessary as compared with other methods of application It seems likely that this technique may be found of great value in special circumstances as for instance during the course of military operations

De Benedetti[946] working in Italy claims that a practically unsinkable diluent for paris green can be prepared by mixing intimately a small quantity of mineral oil with any silicaceous or calcareous dust (except calcium sulphate), and heating it to 250°C to evaporate the excess oil Paris green applied by means of this vehicle is said to persist on stagnant water and to retain its larvicidal power for 24 to 25 days

(See *Bibliography*, Nos 912–1010)

4. Vegetable Larvicides—*Pyrethrum* has been extensively used in recent years in the U S A in the form of an emulsion usually known as the New Jersey Pyrethrum Larvicide (Ginsburg[841], Vannote and Ginsburg[990], Smith[8 8]) Allusion has

shoreline will eventually exceed 7 000 miles one third of which will need protection (Watson and Bishop[709]) This method is also employed very extensively in Russia where in 1937 breeding places extending over an area of 12 000 *square miles were treated It has* been found particularly effective for dealing with peat bogs reed beds ricefields and cotton growing areas intersected by a network of irrigation ditches (Nabokov[978]) It has also been used in Madagascar (Legendre[969] Boyé[951]) Morocco (Sicault[999]) and Indo China (Morin and Martin[974]) In Delhi experimental dusting of paris green from aircraft was carried out in 1936 when it was thought likely that this might prove to be the only practicable *method of controlling mosquito breeding in the low lying tract* bordering the Jumna River The method proved effective but expensive and it was ultimately found possible to deal with breeding in this area with greater thoroughness and at much less cost by other means (Covell and Afridi[581])

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(See *Bibliography*, Nos 942-1010)

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already been made to its employment as a repellent for outdoor meetings (p 94)

A stock mixture is prepared as follows Four gallons of soap solution made by dissolving 16 pounds country soap in hot water and adding 48 ounces methylated spirit, are agitated in *30 gallons of water till a foam is produced* An oil mixture composed of pyrethrum extract (e g, *Pyrocide* 20) 3 gallons pine oil 3 gallons and kerosene oil 60 gallons previously prepared and thoroughly mixed is added to the soap mixture with vigorous agitation till an emulsion is formed Before use the stock mixture is diluted with ten times its volume of water taken from the breeding place The sprayer must be agitated from *time to time in the course of application*

The advantages claimed for this larvicide are that it is cheaper and quicker in action than oil easily transportable, clean and easy to handle kills larvæ and pupæ of both anopheline and culicine mosquitoes is harmless to fish and vegetation, and does not rot rubber hose and washers of sprayers as quickly as does oil A serious disadvantage is that the larvicidal properties of the stock mixture rapidly deteriorate and it has to be made up fresh each day in order to obtain optimum results

More recently, Ginsburg[84] has evolved an improved emulsion *for use on fresh or salt water The formula is 100 U S gallons of* kerosene containing pyrethrum extract equivalent to 100 pounds of flowers 50 U S gallons of water, and 6 pounds of Gardinol W A concentrated (sodium laurel sulphate) To avoid excessive foaming 2 to 3 pounds of wool grease (Degras) may be dissolved in the kerosene before it is added to the mixture of water and emulsifier

The use of *cashew nut shell oil* as a larvicide has been advocated by Wats and Bharucha[894] This is a viscous *tarry oil obtained* from the charred pericarp of the cashew nut, which is a part of the fruit of *Anacardium occidentale* About 32 000 tons of raw cashew nuts are roasted every year in India and the oil is obtained as a by product which is used as a preservative by

fishermen for their boats and nets For use as a larvicide it is mixed with kerosene or with diesel oil in dilutions of from 2 to 5 per cent The addition of 1 per cent stearic acid in kerosene oil is said to increase the stability of the film Disadvantages are that the mixture does not retain its efficacy and must be freshly prepared before use that oils obtained from different sources differ in their toxicity presumably due to adulteration and that the oil has an irritant effect when applied to the skin The authors however believe that these disadvantages can be largely overcome and consider that the oil has distinct possibilities as a larvicide on account of its high toxicity to larvæ rapid action and low cost (Re 1 4 0 per gallon)

5 Naturalistic Control Measures —Under this heading are included those measures by which changes are effected in the natural conditions under which malaria carrying mosquitoes exist rendering them unfavourable to the life and activities of these insects either in the aquatic or adult stages These have been conveniently classed as chemical physical and biological measures by Hackett and his colleagues[65] in their report on an enquiry into the use of such measures, instigated by the League of Nations Malaria Commission from which much of the information given in the following pages has been extracted

(a) CHEMICAL MEASURES

(i) *Pollution of water* —Earlier attempts to check the breeding of malaria vectors by this means have already been discussed (p 83) In Russia mosquito breeding in peat bog pits has been dealt with by adding sulphuric acid to change the reaction of the water This was successful where the bed was of clay but not in the case of a sedge peat bed where the action of the acid was rapidly neutralized by the alkaline reaction of the peat (Pavlova[680])

Certain experiments carried out by Williamson[712] in the Cameron Highlands Malaya are of great interest In one locality,

a small stream in which *A maculatus* had been found breeding in large numbers was converted into a series of ponds in some of which control was effected by the trampling in of cut vegetation whilst in others larvivorous fish were introduced In another case white clay puddled into the sides and beds of pools and of a stream in which there had previously been a considerable amount of breeding was effective Williamson s best known method of larval control is that known as *herbage packing* or *herbage cover* in which fresh cut green vegetation is packed into stagnant or slowly running shallow water to a height of 12 to 18 inches and then trampled in wooden stakes being driven in at the lower end of the packed section in the case of streams and drains to prevent the herbage from being washed away by storm water When packing running water it is essential that there shall be a complete and thick cover of packing above the water level By this means *light is excluded from the water a mechanical barrier to ovipositing* mosquitoes is provided and the water is polluted with organic matter the pH in most cases falling to about 6 0 the last mentioned factor *probably being the most important* The method has been employed in India with complete success as regards the larval control of malaria carrying mosquitoes but frequent in*spection is necessary to ensure that the packing is repaired or* replaced in case of damage due to storm water (Senior White[693] Covell and Harbhagwan[63a] Covell[634])

(ii) *Changing the salt content of water* —A method of dealing with brackish water breeders which include some of the most dangerous malaria carriers known is to increase or diminish the degree of salinity in their breeding places by the admission or exclusion of sea water Near Durazzo Albania a marsh in which *A sacharovi* formerly bred in profusion was converted into a sea water lagoon by installing automatic tide gates with their usual aspect reversed at the mouth of a channel connecting it with the Adriatic (Hackett[650]) A similar result was achieved in Jamaica by reopening a channel and admitting sea water into a large permanent swamp in which the local vector *A albimanus* was breeding

In this locality, which was originally non malarious, a virulent epidemic had followed the closing of the above mentioned channel (Washburn[707])

In the Netherlands the process of reclamation which has been in progress for some years has reduced the breeding of *A atroparvus* by the washing out of salt from the soil due to abundant irrigation brackish water thus being replaced by fresh It is confidently expected that the malaria problem in this area will thus be solved (Swellengrebel and de Buck[612])

(*b*) PHYSICAL MEASURES

(*i*) *Filling by silting*—As a general rule, this is a method which can only be carried out successfully by engineers with experience in this type of work, for the results depend upon an appreciation of the volume of silt in suspension, the reduction in velocity necessary to cause this to be precipitated and the disposal of the residual water On the other hand in the absence of advice from a malariologist there is a risk that such operations may actually favour the breeding of dangerous malaria carrying mosquitoes especially whilst the work is actually in progress A marsh can sometimes be filled by diverting a silt bearing stream into it, a method which has been used with success by Strickland and Murphy[709] in Assam Loops in streams can sometimes be silted up by the use of groins made with jungle stakes interwoven with withies placed at varying angles a technique which has been extensively practised for river training by Worth[710] in Ceylon

(*ii*) *Sluicing* *—The principle underlying this method is the sudden release of water confined in the reservoir created by the

* The earliest example of the operation of sluice gates as an anti mosquito measure is probably the procedure originally recommended by Graham at Lucknow in 1913 which has been carried out continuously since 1916 (Raja Ram[illegible]) The gates of the weir in the River Gumti are lowered once a week from November to May from 5 a m to 12 noon, the purpose being to flush out the drains discharging into the river *above* the weir and to wash out larvae sheltering under the banks into the middle of the stream (Banerjea[illegible])

damming of a stream or drain, in order to flush the channel below the dam A number of larvæ are drowned by the turbulence of the flush itself, and many others, together with eggs and pupæ are stranded on the banks as the wave passes downstream Under favourable conditions, mosquito breeding can sometimes be con trolled throughout several hundred yards of stream by the operation of each sluice It is usually found necessary to adopt subsi diary control measures above the sluice

Excellent results can often be secured in small streams and tea garden drains by the use of kuchcha dams with wooden sluice gates, which can be erected at a very low cost In larger streams, concrete dams are sometimes installed, with gates of wood, or iron which can be raised by means of levers Another type of gate is provided with hinges at the bottom, and held upright by a wire cable, attached to a ring set in concrete in the bed imme diately above the dam. The gate can be made to fall flat on to the stream bed by operating a release clip attached to the cable Gates of this type are easily operated by a single person and enable the whole contents of the reservoir to be released with extreme suddenness

In Malaya (Williamson and Scharff[715]) and Ceylon (Macdonald[665], Worth and Subrahmanyam[717]), and in some localities in India (Ramsay and Anderson[684]), automatic siphon sluices are in use for this purpose, but these usually need frequent attention and inspection, not only for maintenance purposes, but also because they are liable to interference by unauthorized persons Moreover, it is not an uncommon experience that whilst an automatic sluice may function admirably when there is a normal flow of water in the stream, it is apt to fail when this is reduced to a minimum by abnormal drought, which is the very time when its effective operation is most needed It is the author's opinion that hand operated sluices are more suitable for general use, at any rate in India These are less costly than automatic sluices are easily constructed,

are not likely to be interfered with require very little attention and can be operated at any desired moment

(iii) *Flooding* —In Bengal the annual flooding of the delta by the rise of water level in the great rivers provides a striking example of natural control of malaria The silty flood waters are inimical to the breeding of the local vectors the extent of breeding edge is reduced and the raising of the general water level above that of the aquatic vegetation exposes the larvæ to the attacks of fish and other natural enemies The highly malarious condition of the western part of the delta is largely attributable to the exclusion of flooding by road and railway embankments and the embanking of tidal rivers to prevent salt water from spilling over reclaimed land There are obvious grave difficulties in removing existing embankments but it is the declared policy of the Bengal Irrigation Department to abolish embankments step by step wherever practicable and to forbid the erection of any new ones (Curry[637] Griffin[647]) Bentley has pointed out that in Bengal flush irrigation is not practised until October by which time most of the season s anopheline carriers have already been produced He recommends that canals be allowed to run full throughout the flood season so that the largest possible area may be flushed out with silt laden water

(iv) *Fluctuating water level* —Allusion has already been made to the practice of this method in impounded waters in the U S A It has been applied in the Tiber delta in the case of a large marsh which has been surrounded with an embankment and is periodically filled from the river by pumping the primary object being to irrigate 1 000 acres of land (Hackett[650]) In Singapore the water level of a large artificial lake in the Botanical Gardens is raised and lowered periodically with complete success as regards mosquito breeding In Savantvadi south west India the weekly opening of a sluice gate at one end of a lake in the capital of the State serves the double purpose of lowering the water level of the lake and of flushing the stream into which the water is discharged

(v) *Intermittent drying* —This method originally employed by James in India * has been practised in recent years in irrigated tracts in a number of countries e g Algeria (Sergent and Sergent[41]) Bulgaria (Konsuloff[661]) Armenia (Ananyan[619]) Russia (Prosolupov[692] Trukolopov[6?]) Portugal (Hill[654]) Dutch East Indies (Smalt[69?]) and Indo China (Morin[671]) In India field experiments have been conducted in Madras by Russell and Rao[691] The principle is first to flood the fields with water and then cut off the supply for a number of days (usually 3 or 4) in order to minimize mosquito breeding in the fields and small irrigation channels In some cases this procedure appears to increase the yield of the crop whilst in others a slight decrease in yield has been reported

(vi) *Agitation of the water surface* —This method is used in Penang where pools on a hill side are fed by water carried from streams by conduits of split bamboo the terminal section being supported at a height of 4 feet or more above each pool Mosquito breeding is prevented by the consequent splashing and rippling of the water surface (Scharff[69?])

In the U S A reduction in mosquito breeding in large bodies of water has been effected by the action of waves created by driving fast launches round the margins of certain lakes (Kibbey[156])

(vii) *Stagnating or Ponding* —These terms denote the conversion of a stream into a series of pools by means of dams a method first used by Williamson[71?] for the control of *A maculatus* in Malaya The dams were constructed of earth and timber and pond plants and larvivorous fish were introduced This method has been successfully employed by Ejercito[641] in the control of *A minimus* var *flavirostris* in the Philippines

(viii) *Muddying* —This is a term used to indicate the introduction of silty water into breeding places not with the object

* James S P (1903) First report of the anti malarial operations at Mian Mir Sci Mems Govt Ind No 6

of filling them as above described but because silt in suspension is in certain cases fatal to malaria-carrying anophelines This is the basis of the *flood flush* method practised in the Bengal delta by Griffin[647], whereby the silty waters of the rivers are introduced into drainage channels and borrow pits by a system of sluices This is a method which requires considerable engineering skill, and should not be attempted unless this is available

(ix) *Shading* —On p 36 brief mention was made of the earlier experiments of Ramsay and his co workers with the growing of shade giving plants and trees over tea garden drains small streams and swamps in Assam * This method has been greatly developed in subsequent years and has been practised more recently in tea estates in southern India also It is estimated that at least 2 000 miles of channels have been rendered free from the breeding of dangerous mosquitoes during the last 10 years Although shading has proved such a conspicuous success in estates where the population is under strict disciplinary control it is not applicable in uncontrolled rural areas for any break in the shade such as may be produced by cattle or goats or by villagers cutting trees or bushes for fuel will provide a favourable anopheline breeding place

Ramsay[68] has also advocated the control of mosquito breeding in tanks by shading their margins with broad sheets of matting whilst in Malaya the shading of seepage wells by huts of thatch is widely practised and small drains are covered with coconut fronds or with a thatch of coarse grass placed over bundles of twigs with a similar purpose (Scharff[692]) Experiments in artificial shading have also been conducted in Mauritius (Kirk[660]) Argentina (Alvarado[61]) Indo China (Morin[6 1]) and the Dutch East Indies (Overbeel and Stoker[67])

* [illegible]

(c) Biological Measures

(i) *Larvivorous fish*.—In the original edition of this book the use of indigenous fish was recommended in localities where species which prey on mosquito larvæ were available. Experience gained during the past 10 years with *Gambusia* has however led to a modification of this view. Hackett[650] has pointed out that the local fish, after the lapse of centuries have reached a balance with regard to their natural enemies, and their numbers cannot be artificially increased and maintained at an abnormally high level of density, whereas, if an exotic fish can be acclimatized, it will proliferate and maintain its numbers to an extraordinary degree. For instance, *Gambusia* were introduced into Italy in 1922 and have undergone a prodigious multiplication reaching a density far greater than that attained in their native country, contrary to expectation. After the lapse of 18 years, there is no sign of any diminution in their numbers.

Gambusia have been introduced into practically every country where anti-malaria work is in progress. They have been established in many localities in India, and are employed for the control of mosquito breeding in wells in Bangalore and Bombay, and in ornamental waters in Delhi. As has been already explained (p. 81), the utility of fish in the control of malaria is as a rule, strictly limited. It is claimed however, that along the northern coast of Dalmatia, including the peninsula of Istria, anopheline density has been reduced below the threshold of malaria transmission by the agency of *Gambusia* alone (Hackett[650]).

(ii) *Changing the fauna and flora*.—The best known example of this type of control is the treatment of fish ponds in the Dutch East Indies (Overbeek and Stoker[677]). The beds of the ponds are dried for a couple of days at least once a month, after which they are filled with fresh sea water. During the drying period, the fish remain in ditches dug for the purpose in the beds of the ponds. The top algæ are killed by drying, and the development of blue

algæ which grow on the bed of the pond and on which the fish live is promoted The algæ rise to the surface in broad sheets which no larvæ can penetrate Any that may be present in the pond are destroyed by the introduction of larvivorous fish These measures have resulted in a great reduction in the incidence of malaria in the neighbourhood of Batavia

(See *Bibliography* Nos 617–719)

D—GENERAL CONDUCT OF ANTI MALARIA CAMPAIGNS

The provision of a special checking staff of insect collectors entirely separate from the executive staff is of immense value in assessing the efficacy of control measures and of ascertaining the lines on which these may need modification In Delhi where *operations are in progress over an area of some 50 square miles* there is a staff of seven insect collectors to each of whom are assigned certain catching stations If an unexplained local increase occurs in the catch of adults of the vector species the whole of the checking staff is concentrated in that particular section until the source of breeding is discovered The checking staff also make house to house enquiries regarding the occurrence of fever cases in various parts of the urban area (Covell and Afridi[581])

The maintenance of a spirit of enthusiasm among all members of the staff is of vital importance and this depends very largely on the personality of the officer directing the campaign Most if not all of the measures above described depend for their efficacy on the existence of adequate and unremitting supervision For this reason one of the most important factors for the furtherance of anti malaria work in the tropics is the development of communications whereby the cost of supervision can be spread over larger areas Another important factor is the instruction not only of engineers but also of other government officials and employers of labour in the elementary principles of *anti malaria sanitation* The institution of courses in malariology for engineers by the Health Organization of the League of Nations and more recei

by the Government of India marks an important advance in this *direction*

It is only by the diffusion of knowledge among officials as well as the public that we can hope to counteract the natural tendency to curtail expenditure on preventive measures as soon as the incidence of malaria begins to fall and the stimulus to action diminishes particularly in times of financial stringency There are many instances on record where the very success of anti malaria campaigns has led to the reduction of expenditure to a level at which the scheme can no longer operate effectively resulting in a disastrous recrudescence of the disease This is well illustrated by the history of malaria in Bombay (Covell[56])

Most of the advances which have been made in the development of anti malaria measures in recent years owe their origin to an intensive study of the bionomics of malaria carrying anophelines In the author s opinion our further progress largely depends on a still more intimate association of both field and laboratory researches with the actual prosecution of control measures

It is perhaps fortunate that in anti malaria work perfection is so seldom attainable There is always scope for improving existing conditions and for devising new and more effective methods of control, and therein lies the great attraction of this particular branch of public health activity

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988 Russell, P F (1935) — The automatic distribution of paris green for control of Anopheles larvæ *Trans 9th Cong F E A T M*, II, pp 223-232 *RAEB*, XXVI, p 126

989 Russell, P F and Eaton L S (1934) — An automatic distributing machine for paris green mixtures *Phil J Sci*, LIII, 4, pp 497-503 *RAEB*, XXII p 223

990 Russell P F and Jacob V P (1939) — Treating *Casuarina* pits with paris green *J Mal Inst Ind*, II, 3, pp 261-271

991 Russell, P F Knipe F W and Rao T P (1940) — Water instead of dust for diluting paris green *Ind Med Gaz*, LXXV, 12 pp 740-742

992 Russell, P F, and West A P (1932) — Charcoal as a diluent for paris green *Phil J Sci*, XLVIII, 3, pp 291-296 *RAEB*, XX, p 215

993 Russell, P F and West A P (1932) — The effect on Culex larvæ of paris green diluted with charcoal *Ibid*, XLIX 4 pp 651-675 *RAEB*, XXI, p 86

994	SAVAGE J de la M (1933)	Malaria sect on *Rpt Assam Med Res* oc 1933 7 pp *PAEL* XXII p 141 (R ce bran a diluent)
995	SAZONOV I V and STREGULINA F S (193)	Control of mosquito larvæ in Arm nia *Mater 1st All Un on Ar o Chem C nf Moscow* 193 pp 18)-210 *RAEB* XX p 15 (A rcraft dust n)
996	SEN P (193)	an par s green k l fish? *Bengal Pub Hlth J* I 1 pp 9 1° *TDB* XXXVII p 365
997	SERGENT Et (1932)	Use of paris green as a larv c de n Algeria *Arch Inst Pa t Alge* X 3 pp 35 - 3 8 *PAEB* XXI p 70
998	SERGIEV I G *et al* (1939	A mechan al sprayer for larvicidal d ts Serna) *Med Pa as* VIII 3 pp 98 3 *RAEB* XXVIII p 36 Mounted on boat or tru k and worked by a motor
	SHIK V N I and SHCHERBAKOVA O A (1937)	S No 8 Effect on ri e r ps
	SHIPITZINA N K (1938)	S No 8 6
999	SICAULT G (1935)	Appl at n f par green from aircraft n Morocco *Bull Inst Hyg Maroc* pp 93 1 r *RAEB* XXIV p 1 4
1000	SICAULT G (193)	Manufa ture tr a l use f p ris green larvicide m xtures n Morocco *Bull Soc Pa h Exot* XXX " pp 84-58 *TDB* XXXIV p 315
	SILER J F (193)	See No 610 (*R pt for* 1931) (Air raft dusting
1001	SWEET W C and RAO B A (1933)	Notes on malar a in Mysore State IV Experimental ontrol with paris green and plasm qu e *Rec Mal Surv Ind* III 4 pp 689 718
1002	SWEET W C and RAO B A (1934)	Notes on malaria n Mysore State V The control of anophel ne breed n in Bangal re City and its cost in Mysore Sta e *R Mal Surv Ind* IV 2, pp 95-110
1003	SYDDIQ M M (1938)	Observat ns of pract al importance for the malari logist *Ind Med Gaz* LXXIII 11 pp 6 6-679 *RAEP* XXVII p 1?3 (Effects on rice crops.)

1004 SYKES, C B (1931 32) — Observations on anophelines and malaria in Kitale, with notes on experimental control with paris green *Kenya and E Afr Med J* VIII 9–10, pp 256–267 280 283 *RAEB*, XX, p 76

1005 VARIOUS AUTHORS (1932) (RUSSIAN) — First conference in the U S S R on use of aircraft in malaria control *Med Paras*, I 2, pp 65–116 *RAEB*, XXII, p 87

1006 WALLACE, R B (1933) — Paris green as a larvicide on an inland hilly estate in Malaya *Trans Roy Soc Trop Med Hyg* XXVII, 2 pp 131–146 *RAEB*, XXI, p 229

1007 WATSON, R B (1936) — Airplane dusting for Anopheles larvae control *South Med J*, XXIX 8 pp 862 867 *RAEB*, XXV, p 117

WATSON R B and BISHOP, E L (1940) — See No 709 (Aircraft dusting)

1008 WATSON R B KIKER, C C, and JOHNSON, H A (1938) — The role of airplane dusting in the control of Anopheles breeding associated with impounded waters *U S A Pub Hlth Rpts* LIII, 7 pp 251–263 *RAEB* XXVI, p 132

1009 WEST A P and RUSSELL, P F (1932) — Paris green partially adsorbed on charcoal as a larvicide *Phil J Sci* XLVIII, 4, pp 545–561 *RAEB*, XX, p 236

1010 YAO Y T, and WU C C (1935) — Anti larval measures by the use of paris green *Trans 9th Cong F E A T M* II, pp 213–221 *RAEB*, XXVI, p 126

YURCHAK, F F, and BOZHENKO, V P (1939) — See No 898 (Barber s method)

Repellents

GINSBURG J M (1935) .. See No 842 (Pyrethrum emulsion)

1011 GINSBURG J M (1935) — Protection from mosquito bites in outdoor gatherings *Science* LXXXII, 2134, pp 490–491 *RAEB* XXIV, p 34 (Pyrethrum emulsion)

1012 GINSBURG, J M (1936) — Protection of outdoor gatherings from the mosquito pest *Procs 23rd Ann Mtg N J Mosq Ext Ass* pp 166–173 *RAEB* XXIV, p 270 (Pyrethrum emulsion)

1013 GINSBURG, J M (1937) — Protection of outdoor meetings from the mosquito pest *Ibid 24th Mtg* pp 5–11 *RAEB* XXV, p 265 (Pyrethrum emulsion)

1014 GRANETT, P (1938) — Comparison of mosquito repellency tests under laboratory and field conditions *Proc 25th Ann Mtg N J Mosq Ext Ass*, pp 51–57 *RAEB*, XXVII, p 29

1015 GRANETT, P (1940) — The development of a practical mosquito repellent *Ibid*, 27th *Mtg*, pp 36–43
(Stay-way Insect Repellent Lotion', mixture of diethylene glycol monobutyl ether acetate, diethylene glycol monoethyl ether, ethyl alcohol, corn oil and perfume)

1016 KING W V *et al* (1937) — Experiments in Florida in repelling mosquitoes by outdoor spraying *Ibid*, 24th *Mtg*, pp 163–172 *RAEB*, XXV, p 265
(Pyrethrum emulsion)

1017. MACKAY C G (1938) — An effective repellent for biting insects *Canad Entom*, LXX, 8, pp 175–176 *RAEB*, XXVII, p 14.
(Oil of thyme, ½ oz, Extract of pyrethrum 1 oz Castor oil, 2 3 oz)

1018 MACKAY C G (1939) — Studies on repellents for biting flies *Ibid.*, LXXI, 2, pp. 38–44

1019 MAIL, G A (1934) — The mosquitoes of Montana *Bull Montana Agric Exp Sta*, No 288 72 pp *RAEB*, XXII, p 182
(Derivatives of salicylic acid)

MEILLON B DE (1934) — See No 1059
(Citronella oil)

SYDDIQ M M (1938) — See No 1003
(Beeswax, 2 dr spermaceti 4 dr, coconut oil 4 dr fuller's earth, 4 dr liq paraffin, 1 oz, oil of citronella, 1 oz carbolic acid, 10 min)

1020 VANNOTE, R L (1937) — Methods of applying the larvicide as a repellent *Proc 24th Ann Mtg N J Mosq Ext Ass.*, pp 11–13 *RAEB*, XXV p 265

Screening.

1021 BESSLER C (1938) — On anti-mosquito screens *Riv Mal.*, XVII, 1, pp 51–61 *RAEB*, XXVI, p. 159
(Steel, aluminium, monel metal, bronze, galvanized iron; brass; copper)

1004 SYMES C B (1931-32) Observations on anophelines and malaria in Kitale, with notes on experimental control with paris green *Kenya and E Afr Med J*, VIII 9-10, pp 256-267 280 283 *RAEB*, XX p 76

1005 VARIOUS AUTHORS (1932) (RUSSIAN) First conference in the U S S R on use of aircraft in malaria control *Med Paras*, I 2, pp 65-116 *RAEB*, XXII p 87

1006 WALLACE, R B (1933) Paris green as a larvicide on an inland hilly estate in Malaya *Trans Roy Soc Trop Med Hyg*, XXVII 2 pp 131-146 *RAEB*, XXI, p 229

1007 WATSON, R B (1936) Airplane dusting for Anopheles larvæ control *South Med J*, XXIX 8 pp 862 867 *RAEB*, XXV, p 117

WATSON, R B and BISHOP, E L (1940) *See* No 709 (Aircraft dusting)

1008 WATSON R B KIKER C C, and JOHNSON H A (1938) The role of airplane dusting in the control of Anopheles breeding associated with impounded waters *U S A Pub Hlth Rpts*, LIII 7 pp 251-263 *RAEB*, XXVI, p 132

1009 WEST A P and RUSSELL, P F (1932) Paris green partially adsorbed on charcoal as a larvicide *Phil J Sci* XLVIII 4, pp 545-561 *RAEB*, XX, p 236

1010 YAO Y T, and WU, C C (1935) Anti larval measures by the use of paris green *Trans 9th Cong F E A T M*, II pp 213 221 *RAEB* XXVI, p 126

YURCHAK, F F, and BOZHENKO V P (1939) *See* No 898 (Barber s method)

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1012 GINSBURG, J M (1936) Protection of outdoor gatherings from the mosquito pest *Proc 23rd Ann Mtg N J Mosq Ext Ass*, pp 166-173 *RAEB*, XXIV, p 270 (Pyrethrum emulsion)

1013 GINSBURG J M (1937) Protection of outdoor meetings from the mosquito pest *Ibid* 24th *Mtg* pp 5-11 *RAEB*, XXV p 265 (Pyrethrum emulsion)

1014 GRANETT P (1939) Comparison of mosquito repellency tests under laboratory and field conditions *Proc* 25th *Ann Mtg N J Mosq Ext Ass*, pp 51–57 *RAEB*, XXVII p 29

1015 GRANETT P (1940) The development of a practical mosquito repellent *Ibid* 27th *Mtg*, pp 36–43
('Stay way Insect Repellent Lotion' mixture of diethylene glycol monobutyl ether acetate diethylene glycol monoethyl ether, ethyl alcohol, corn oil and perfume)

1016 KING W V *et al* (1937) Experiments in Florida in repelling mosquitoes by outdoor spraying *Ibid* 24th *Mtg* pp 163–172 *RAEB* XXV, p 265
(Pyrethrum emulsion)

1017 MACKAY C G (1938) An effective repellent for biting insects *Canad Entom* LXX 8 pp 175–176 *RAEB* XXVII p 14
(Oil of thyme, ½ oz Extract of pyrethrum 1 oz Castor oil, 3 oz)

1018 MACKAY C G (1939) Studies on repellents for biting flies *Ibid*, LXXI 2 pp 38–44

1019 MAIL C A (1934) The mosquitoes of Montana *Bull Montana Agric Exp Sta* No 288 72 pp *RAEB* XXII p 182
(Derivatives of salicylic acid)

MEILLON B DE (1934) See No 1059
(Citronella oil)

SYDDIQ M M (1938) See No 1003
(Beeswax 2 dr spermaceti 4 dr, coconut oil 4 dr fuller's earth, 4 dr liq paraffin, 1 oz, oil of citronella 1 oz carbolic acid 10 min)

1020 VANNOTE R L (1937) Methods of applying the larvicide as a repellent *Procs* 24th *Ann Mtg N J Mosq Ext Ass* pp 11–13 *RAEB*, XXV p 265

Screening

1021 BESSLER C (1938) On anti mosquito screens *Riv Mal*, XVII 1 pp 51–61 *RAEB*, XXVI, p 159
(Steel aluminum monel metal bronze galvanized iron brass copper)

1004 SYMES, C B (1931-32) Observations on anophelines and malaria in Kitale, with notes on experimental control with paris green *Kenya and E Afr Med J*, VIII, 9-10, pp 256-267, 280 283 *RAEB*, XX, p 76

1005 VARIOUS AUTHORS (1932) (RUSSIAN) First conference in the U S S R on use of aircraft in malaria control *Med Paras*, I, 2, pp 65-116 *RAEB*, XXII, p 87

1006 WALLACE, R B (1933) Paris green as a larvicide on an inland hilly estate in Malaya *Trans Roy Soc Trop Med Hyg*, XXVII, 2 pp 131-146 *RAEB*, XXI, p 229

1007 WATSON, R B (1936) Airplane dusting for Anopheles larvæ control *South Med J*, XXIX, 8, pp 862-867 *RAEB*, XXV, p 117

WATSON, R B, and BISHOP, E L (1940) *See* No 709 (*Aircraft dusting*)

1008 WATSON, R B, KIKER, C C, and JOHNSON, H A (1938) The role of airplane dusting in the control of Anopheles breeding associated with impounded waters *U S A Pub Hlth Rpts*, LIII, 7, pp 251-263 *RAEB*, XXVI, p 132

1009 WEST, A P, and RUSSELL, P F (1932) Paris green partially adsorbed on charcoal as a larvicide *Phil J Sci*, XLVIII, 4, pp 545-561, *RAEB* XX, p 236

1010 YAO Y T, and WU, C C (1935) Anti larval measures by the use of paris green *Trans 9th Cong F E A T M*, II, pp 213-221 *RAEB*, XXVI, p 126

YURCHAK, F. F, and BOZHENKO, V P (1939) *See* No 898 (Barber's method)

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1012 GINSBURG, J M (1936) Protection of outdoor gatherings from the mosquito pest *Proc 23rd Ann Mtg N J Mosq Ext Ass*, pp 166-173 *RAEB*, XXIV, p 270 (Pyrethrum emulsion)

1013 GINSBURG, J M (1937) Protection of outdoor meetings from the mosquito pest *Ibid*, 24th *Mtg* pp 5-11 *RAEB*, XXV, p 265 (Pyrethrum emulsion)

1014 GRANETT, P (1938) — Comparison of mosquito repellency tests under laboratory and field conditions *Proc 25th Ann Mtg N J Mosq Ext Ass*, pp 51–57 *RAEB*, XXVII, p 29

1015 GRANETT P (1940) — The development of a practical mosquito repellent *Ibid*, 27th *Mtg*, pp 36–43 ('Stay way Insect Repellent Lotion', mixture of diethylene glycol monobutyl ether acetate, diethylene glycol monoethyl ether, ethyl alcohol, corn oil and perfume)

... KING W V et al (1937) — Experiments in Florida in repelling mosquitoes by outdoor spraying *Ibid*, 24th *Mtg*, pp 163–172 *RAEB*, XXV, p 265 (Pyrethrum emulsion)

17. MACNAY C G (1938) — An effective repellent for biting insects *Canad Entom* LXX, 8, pp 175–176. *RAEB*, XXVII p 14 (Oil of thyme, ½ oz, Extract of pyrethrum 1 oz Castor oil, 2 3 oz)

1018 MACNAY C G (1939) — Studies on repellents for biting flies *Ibid*, LXXI, 2, pp 38–44

1019 MAIL G A (1934) — The mosquitoes of Montana *Bull Montana Agric Exp Sta*, No 288 72 pp *RAEB*, XXII, p 182 (Derivatives of salicylic acid)

MELLON R DE (19.4) — See No 1059 (Citronella oil)

SYDDIQ M M (1938) — See No 1003 (Beeswax, 2 dr spermaceti 4 dr, coconut oil 4 dr fuller's earth, 4 dr liq paraffin, 1 oz., oil of citronella, 1 oz carbolic acid, 10 min)

1020 VANNOTE, R L (1937) — Methods of applying the larvicide as a repellent *Proc 24th Ann Mtg N J Mosq Ext Ass*, pp 11–13 *RAEB*, XXV, p 265

Screening

21 BESSLER C (1938) — On anti mosquito screens *Riv Mal*, XVII, 1 pp 51–61 *RAEB*, XXVI, p 159 (Steel aluminium monel metal brass, bronze, galvanized iron copper)

1022 BLACKLOCK, D B (1935) .. Screencloth for houses in the tropics *Ann Trop Med Paras*, XXIX, 2 pp 261-263 *RAEB*, XXIII, p 229 (Recommends Barronia metal)

1023 BLACKLOCK, D B (1937) Screencloth for houses in the tropics *Ibid*, XXXI, 3, p 447. *RAEB*, XXVI, p 39

1024 BOOKER, C G (1935) Ann Rpt S Afr Rlwys and Harbours Hlth Organization *Rpt Dept Pub Hlth S Afr*, 1934-35, pp 79-98 *RAEB*, XXIV, p 77 (Monel metal screening, 16 mesh, 30 ISWG)

1025 BROWN J Y (1934) Safe mosquito nets for use in Nigeria *W Afr Med J*, VII, 4, pp 147-148 *RAEB*, XXII, p 213 (Mesh 25 26)

1026 DAVEY, T H, and GORDON, R M (1938) The size of aperture necessary in screen cloth *Ann Trop Med Paras*, XXXII, 4, pp 413-424 *RAEB*, XXVII, p 130 (Must not exceed 0 017 in, i e, 16 mesh, 28 ISWG)

1027 FARLE W C (1932) Anti mosquito screening and screening materials *Puerto Rico J Pub Hlth Trop Med*, VIII, 2, pp 227-234 *RAEB*, XXI, p 89 (Bronze, monel metal; galvanized iron recommends 12 mesh screen of 0 015 in wire)

1028 GATER B A R (1930) Mosquito nets *Malay Med J*, V, 1, pp 29-32 *RAEB*, XIX, p 5 (Recommends 22/23 mesh and 60/100 cotton)

1029 GIGLIOLI, G (1933) Aluminium gauze for mosquito screening *Riv Mal*, XII, 1, pp 196-197 *RAEB*, XXI, p 181.

HARGREAVES, H (1936) See No 845 (Recommends 14 mesh, 30 ISWG wire gauze, or 25/26 mesh nets woven of 30 or 40/60 counts cotton)

1030 IREDELL A W (1933) Mosquito proofing carried out by the Royal Air Force in India *Jl R A M C*, IX, 1, pp 33-37 Also in *Procs Roy Soc Med*, XXVI, 1, pp 1-5 *RAEB*, XXI, p 65

1031 MARNEFFE, H (1935) The mosquito net in malaria prevention in Indo China *Bull Soc Méd Chir Indochine*, XIII, 9, pp 1265-1297 *RAEB*, XXIV, p 126

1032 Martzinovskii F I (1933 1934) The ... mosquito net Bull Soc Path Exot XXVI 8 pp 1018 1020 Also in ... Larva III 4 PP 313 314 RAEB XXII p 15

1033 Meleney H E and Griffin R B (1931) Mosquito proofing and treatment in the control of malaria on a plantation. South Med J XXIV 5 pp 418 4 4

1034 Moon J E (1931) Possibilities of mosquito-proofing all rural homes in a county Ibid pp 431–439

1035 Mulligan H W and Majid S A (1931) Efficacy of wire gauze screening of different apertures in excluding anopheline mosquitoes in India Rec Mal Sur Ind III 1 pp 163–169 (Aperture of 0·013 to 0·020 in necessary for absolute exclusion but 0·055 in considered adequate for general use)

1036 Ralston I G (1931) Manufacture and life of screen wire South Med J XXIV 5 pp 449–451 RAEB XX p 1 (Recommends electro galvanized steel wire)

1037 Russell P F and Nono A M (1934) A mosquito net for use in the Philippines Phil J Sci LIII ... pp 107 140 RAEB XXII p 146 (Sinamay netting made from fibres of Musa textilis)

1038 Shmeleva Y D and Semenova M F (1937) Value of screening houses and using mosquito nets Med Parasit VI ... pp 50–58 RAEB XXVI p 48

1039 Zavattari E (1935) A simplified mosquito net for tropical countries Riv Mal XIV 3 pp ... 290 RAEB XXIII p 287

Sprays

1040 Anon (1929) Dept Entomology and Zoology Ann Rpt Tech ... Dept Agric ... 1928 29 B ll No 17 (Pyrethrum–carbon tetrachloride–petrol spray)

1041 Anon (1938) Destruction of mosquitoes in aeroplanes. A test flight Lancet CCXXXIV p 1414 RAEB XXVII p 31 (Aqueous base extract of pyrethrum)

1042 Baker F (1934) Insecticidal sprays for the destruction of mosquitoes and flies J R A M C LXII 6 pp 411–418 RAEB XXII p 1 9 (Pyrethrum kerosene citronella oil and petrol)

1043 BOER H DE (1937) — *Anti mosquito measures in aerodrome* B ll Off Int Hyg Pub XXIX 6 pp 1157 1158 *RAEB* XXV p 253

BOOKER C G (1935) — See No 1024 (Pyrethrum spray)

1044 BOOKER C G (1936) — Ann Rpt S Afr Rlwys and Harbours Hlth Organ *Rpt Dept P b Hlth S Afr* 1935 36 pp 93 121 *RAEB* XXV p 137 (*Pyrethrum spray*)

1045 CALDWELL A F (1938) — A note on the chemistry and preparation of insect sprays containing pyrethrum *J Mala Br B t Med Ass* I 4 pp 336–341 *RAEB* XXVI p 158

1046 CHOPRA B L (1938) — Anti malarial measures in the railway area at Delhi *Ind Med Gaz* LXXIII 3 pp 150–151 *RAEB* XXVI p 148 (*Pyrethrum spray*)

1047 COVELL, G (1940) — The cultivation of pyrethrum in India *Planters Chronicle* XXXV 18 pp 370–371

1048 COVELL G MULLIGAN H W and AFRIDI M K (1938) — An attempt to control malaria by the destruction of adult mosquitoes with insecticidal sprays *J Mal Inst Ind* I 1 pp 105–113 (Pyrethrum spray)

1049 GERTLER S I and HALLER H L (1939) — *The pyrethrin content of home made* fly sprays *Soap* XVI pp 93–94 *RAEB* XXVII p 155

1050 GNADINGER C B (1936) — Pyrethrum flowers Minneapolis Minn Ed 2 (with Suppt)

1051 GRAY C G (1931) — Sensitivity to insecticides *J Amer Med Ass* XCVI 3 p 213 (Dermatitis following use of Flit)

GRIFFITTS T D H *et al* (1935) — See No 806 (*Pyrethrum spray*)

1052 HICKS E P and CHAND D (1936) — Transport and control of *Aedes aegypti* in aeroplanes *Rec Mal Surv Ind* VI 1 pp 73 90 (Pyrethrum spray)

1053 HOLT P L (1931) — A new mosquito spray *Mil Surg on* XXIX 6 pp 625–627 *RAEB* XX p 122 (Pyrethrum with carbon bisulphide *acetone and chloroform*)

1054 HOLT R L and KINTNER J H (1932) — Anti mosquito sprays *Phil J Sc* XLVII 4 pp 433–438 *RAEB* XX p 122

1055. Hoyer, D G (1936) — Effect of metals on fly sprays (Pyrethrum liquid insecticides) *Soap*, XII, Reprint No 1, 2 pp *RAEB*, XXIV, p 151.

1056. Jitta, N M J (1935) — Destruction of mosquitoes in aircraft *Bull Off Int Hyg Pub*, XXVII, 7, pp 1360–1361 *RAEB*, XXIII, p. 247 (Pyrethrum spray)

1057 Lowman M S, and Sullivan, W N (1938) — Pyrethrum evaluation Relation of pyrethrin content of pyrethrum flowers to their toxicity to mosquito larvæ *Soap* XIV 11 pp 89–91, 93, 119 *RAEB* XXVII, p 64

McDaniel F I (1939) — See No 856 (Popular account)

1058 Mackie, F P and Crabtree, H S (1938) — The destruction of mosquitoes in aircraft *Lancet*, CCXXXV pp 447–450 *RAEB*, XXVII, p 118 (Aqueous base pyrethrum spray)

1059 Meillon, B de (1934) — Observations on *Anopheles funestus* and *Anopheles gambiæ* in the Transvaal S Afr Inst for Med Res Pbn 248 pp (Pyrethrum spray)

1060 Meillon B de (1936) — Control of malaria in S Africa by measures against adult mosquitoes in habitations. *Quart Bull Hlth Organ, L of N*, V, 1, pp 134–137 *RAEB*, XXIV, p 153 (Pyrethrum spray)

1061 Moreau P (1939) — Value of insecticidal sprays in malaria control *Rev Méd Franc Extr Orient* XVI, 3, pp 264–274 *RAEB*, XXVII p 138 (Aqueous base pyrethrum spray)

1062 Nijkamp, J A and Swellengrebel, N H (1934) — Destruction of Anopheles with Pyrethrum preparations *Ned Tijd Geneesk*, LXXVIII, 21, pp. 2327–2338 *RAEB*, XXII p 193

1063 Pannewitz, F (1931) — On the toxicity of the combinations of mineral oils with essential oils in insecticides with a petroleum base. *J Desinfekt* XXIII, 8, pp 339–342 *RAEB*, XIX, p 231

1064 Richards, H (1938) — Report on the disinfestation of aircraft at Khartoum *Bull Off Int Hyg Pub*, XXX, 3, pp 563–567 *RAEB*, XXVI, p 157 (Pyrethrum extract, 5 8, citronella oil, 2 carbon tetrachloride, 49, kerosene oil, 43 2)

1065 RICHARDSON, H H (1932) Insecticidal studies of mid continent distillates as bases for pyrethrum extracts *Indust Engng Chem*, XXIV, 12, pp 1394–1397 *RAEB*, XXII, p 10

1066 ROSS, G A P (1936) Insecticide as a major method of control of malaria *Quart Bull Hlth Organ, L of N*, V, 1, pp 114–131 *RAEB*, XXIV, p 153
(Pyrethrum spray)

1067 ROSS G A P (1938) Automatic destruction of mosquitoes in aircraft *Bull Off Int Hyg Pub* XXX, 9, pp 2002–2031 *RAEB*, XXVII, p 48
(Aqueous base pyrethrum spray)

1068 RUSSELL, P F, and KNIPE, F W (1939) Malaria control by spray killing adult mosquitoes *J Mal Inst Ind*, II, 3, pp 229 237
(Pyrethrum spray)

1069 RUSSELL, P F, and KNIPE F W (1940) *Malaria control by spray killing adult* mosquitoes Second season's results *Ibid*, III, 4, pp 531–541
(Pyrethrum spray)

1070 SCHUFFNER, W A P, and SWELLENGREBEL, N H (1938) Report for 1936 and 1937 of the Malaria Commission of the Health Council of Holland *Versl Meded Volk*, Reprint 26 pp *RAEB*, XXVII p 51
(Pyrethrum spray)

1071 SINTON, J A, and WATS R C (1935) The efficacy of various insecticidal sprays in the destruction of adult mosquitoes *Rec Mal Surv Ind*, V, 3, pp 275–306

1072 SWELLENGREBEL, N H (1934) Seven years' experience in Anopheles control at Medemblik *Ned Tijd Geneesk*, LXXVIII, 3, pp 315–353 *RAEB*, XXII, p 116
(Kerosene with 0 5 per cent pyrethrum extract, 0 5 per cent oil of sassafras, and 2 per cent methyl salicylate)

1073. SWELLENGREBEL, N H, *et al* (1936) Investigations on the transmission of malaria in some villages north of Amsterdam *Quart Bull Hlth Org L of N*, V, 2, pp 295–352 *RAEB*, XXIV, p 283
(Spraying confined to houses with several children)

SYMES, C. B. (1935) . *See* No. 810

1074 Symes, C. B. (1937). Insects in aircraft. *Bull. Off. Int. Hyg. Pub.*, XXIX, 6, pp. 1150–1157. *R.A.E.B.*, XXV, p. 253. (Pyrethrum kerosene-carbon tetrachloride.)

1075 Thornton, L. N. (1933–36). Malaria. *Rpts. Dept. Pub. Hlth. S. Afr.*, 1932–35. *R.A.E.B.*, XXII, p. 53; XXIII, p. 8; XXIV, p. 76; XXV, p. 136. (Pyrethrum spray.)

1076 Viktorov, S. V. (1938). Destruction of adult mosquitoes. *Med. Paras.*, VII, 1, pp. 61–68. *R.A.E.B.*, XXVI, p. 219. (Watery solution of soft natron soap and methylated spirit.)

1077 Wats, R. C., and Bharucha, K. H. (1940). The choice of mechanical sprayers for mosquitocides. *J. Mal. Inst. Ind.*, III, 1, pp. 129–136.

1078 Wats, R. C., and Singh, J. (1937). Mosquitocidal value of indigenous *Derris* and other drugs. *Rec. Mal. Surv. Ind.*, VII, 1, pp. 109–147. (Sprays containing 65 different substances.)

1079 Welch, L. V. (1939). Insects found in aircraft at Miami, Fla., in 1938. *U. S. A. Pub. Hlth. Rpts.*, LIV, 14, pp. 561–566. *R.A.E.B.*, XXVII, p. 215. (Pyrethrum spray.)

1080 Whitfield, F. G. S. (1939). Air traffic insects and disease. *Bull. Ent. Res.*, XXX, 3, pp. 365–442.

1081 Williams, C. L. (1940). Disinsectization of aircraft. *U. S. A. Pub. Hlth. Rpts.*, LV, 23, pp. 1005–1010. (Description of special spray gun.)

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(Cattle stabled between reservoir and village)

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APPENDIX I

Anti-Mosquito Equipment.

Article	Where obtainable
	Paris Green Equipment
Haversack	Dina Nath & Sons Gumti Bazaar Lahore
Mixer	Dina Nath & Sons Lahore Shaw Wallace & Co 4 Bankshall St Calcutta General Export Co 63 Ezra St Calcutta
Paris green	F Klein 1 Royal Exchange Place Calcutta Bishan Das Arora & Sons Bharat Buildings Nisbet Ld Lahore Dina Nath & Sons Lahore General Export Co Calcutta Hoyle Robson Barnett & Co Ltd Agents [illegible]
Peerless Dust Gun	Shaw Wallace & Co Calcutta
Screener	Shaw Wallace & Co Calcutta Dina Nath & Sons Lahore
Soapstone powder	[illegible]
	Oiling Equipment.
Eclair No. 2 Model Knapsack Sprayer (Vermorel Eclair) 3½ gals.	McLeod & Co Post Box 78 Dalhousie Sq., Calcutta Massey's Ltd., Main Rd., Poyapuram Madras.

Anti-Mosquito Equipment—*concld*

ARTICLE	WHERE OBTAINABLE.
Oiling Equipment—*concld.*	
Four Oaks Ross Knapsack Sprayer, 3½ gals	Planters' Stores and Agency Co, Calcutta
Fuel (diesel) oil, Malariol	Burmah Shell Oil Storage and Distributing Co. of India, Ltd, Ambala, Bombay, Calcutta, Delhi, Karachi
Equipment for Spray-killing Adult Mosquitoes.	
Deskito, Pye fly	Stafford Allen & Sons, London, Anglo Siam Corporation, Ltd, Ewart House, Bombay
Pyrocide 20	F S Kerr & Co, Vulcan House, Ballard Estate, Bombay.
Pyrefume	Penick & Co, 132, Nassau St, New York, U S A; Standard Chemical & Pharmaceutical Co, Bombay
Pyrin, Pyrentol 20	John Powell & Co, 114, East St, New York, U. S A; Standard Chemical & Pharmaceutical Co, Bombay
Shell tox	Burmah Shell Oil Storage and Distributing Co of India, Ltd
Power Sprayers	Gillanders Arbuthnot & Co, Connaught Place, [illegible]
Wire Gauze.	
Wire Gauze Screen (Greening Rustless Bronze Gauze Wire)	Wright & Partners, Ltd, 19, Aurangzeb Rd, New Delhi

APPENDIX II

Table of Equivalents

Measures of Capacity

1 Cubic centimetre = 0 0352 ounce
1 Ounce = 28 4123 cubic centimetres
1 Pint = 568 2454 cubic centimetres
1 Gallon = 160 ounces
1 Litre = 0·2199 gallon

1 Gallon = 4 546 litres
1 United States gallon = 0 833 Imperial gallon
1 Imperial gallon = 1 2 United States gallons

Measures of Weight

1 Gramme = 15 432 grains
1 Grain = 0 0648 gramme
1 Pound = 0 4535 kilogramme
1 Kilogramme = 2 2046 pounds
1 Ton = 2 240 pounds

1 Fluid drachm = 3 5437 grammes or 54 6875 grains
1 Fluid ounce = 437 5 grains or 28 350 grammes

Measures of Length and Area.

1 Centimetre = 0·3937 inch
1 Inch = 2 54 centimetres
1 Metre = 1·0936 yards
1 Yard = 0 9144 metre
1 Foot = 30·48 centimetres

1 Chain = 66 feet
1 Acre = 4 840 square yards
1 Square mile = 640 acres
1 Acre = 0 4047 hectare
1 Hectare = 2 4711 acres

Approximate Equivalents

1 Millimetre = $\frac{1}{25}$ inch
1 Centimetre = $\frac{2}{5}$ inch
1 Metre = 39$\frac{3}{8}$ inches
1 Foot = 30 centimetres
5 Miles = 8 kilometres
1 Kilogramme = 2$\frac{1}{5}$ pounds

1,000 Kilogrammes = 1 ton
1 Litre = 1$\frac{3}{4}$ pints
1 Pound = 453$\frac{1}{2}$ grammes
5 Kilogrammes = 11 pounds
1 Gramme = 15 grains
1 Hundredweight = 50 kilogrammes.

INDEX

Pyefly

For Sprays that Kill!

PYEFLY is an Empire product a concentrated Liquid Extract of Pyrethrum manufactured in England from Empire grown flowers. It is biologically standardised to a specific strength so that when 1 part is diluted with 64 parts of kerosene a highly toxic insecticide is produced. Biological tests have proved that PYEFLY at this dilution gives a 100% efficient spray for use against flies etc. Much has been written and possibly will be written on the comparative values of chemical and biological tests. Both are necessary but it is the biological test which proves its actual toxicity.

The toxic principles Pyrethrins being organic bodies are prone to decomposition, but certain precautions introduced into our method of manufacture ensure their stability.

The Malaria scourge is sufficiently well known that comment is unnecessary so also is the fact that where adequate anti-mosquito measures have been applied there has been a marked decrease in Malaria fever. Until such time as all mosquito breeding places are exterminated Malaria fever will continue, unless the adult mosquitoes are destroyed. Proof that Pyrethrum sprays if properly used will do this is already known, thanks to the experiments carried out by various authorities in India.

The reason why PYEFLY is strongly recommended as the toxic principle of fly and mosquito sprays is that it has a guaranteed stabilised strength calculated by biological tests.

Besides mosquitoes there are other bacteria carrying insects sand flies etc. which can be controlled with Pyrethrum sprays of the right sort if used thoroughly.

Formula —

Pyefly	1 part
Citronella oil	4 parts
Kerosene	59 parts

STAFFORD ALLEN & SONS LIMITED
Wharf Road, London, E.C. 2
England

Agents —THE ANGLO-THAI CORPORATION, LTD.
P. O. Box No. 70, BOMBAY